Abstract

Water management in a reservoir-regulated river basin poses challenges due to the storage and operations of upstream reservoirs. This study employed a novel approach, combining a distributed hydrological model (National Hydrological Model-India (NHM-I)) and Machine Learning (ML) for effective water management. To enhance the NHM-I model's credibility in reservoir-regulated basins, reservoir and water demand modules are developed to model reservoir operations and simulate various water demands. Reservoir inflow and irrigation demand forecasts are essential for optimising water releases and ensuring effective real-time water management. Real-time streamflow forecasting in a reservoir-regulated basin becomes challenging without real-time forecasts of upstream reservoir outflows. In this context, the ML model is embedded with the reservoir module of the NHM-I model to forecast real-time streamflow. This study selects the Long Short-Term Memory (LSTM) model as it outperforms other ML models in terms of both performance and explainability. The water demand module of the NHM-I model is utilised to forecast irrigation demands. Damodar river basin (which includes Tenughat, Konar and Tilaiya reservoirs upstream, and Panchet and Maithon reservoirs downstream) is selected as the study area. The reservoir module integrated NHM-I model captured daily reservoir inflows (NSE > 0.57), outflows (NSE > 0.77), and storage levels (NSE > 0.79) satisfactorily. Also, the developed water demand module effectively simulated the spatial and temporal variations of water demands in the study area. In forecasting, bias-corrected Global Forecast System (GFS) data of 1–5 days lead is used with the LSTM model to forecast the streamflow. With the forecasts of upstream reservoirs, the Panchet and Maithon reservoirs' inflows are forecasted well using the hybrid approach with NSE values above 0.88 and 0.78, respectively. The water demand module, utilising GFS forecasts, accurately forecasted irrigation demands in the command area up to 5-day lead, with absolute percentage errors ranging from 3.48% to 27.31% in different seasons. With the inflows and irrigation demand forecasts, the Panchet and Maithon reservoirs satisfied the downstream demands and reduced the floods. Therefore, the proposed hybrid approach has substantial potential for efficient water management in a reservoir-regulated river basin.

Keywords: Bias correction, GFS forecasts, Irrigation demand, LSTM model, NHM-I, Reservoir module