Abstract

Flood accounts for about one-third of all natural disasters around the globe. Due to changing climate, extreme floods have recently become more frequent in the tropical region. Keeping in view the role of precipitation driver as a proxy of catchment wetness on flood generation, no study has evaluated the relationship between the lagged predecessor rain events and the sub-catchment scale runoff. In India, the India Meteorological Department provides daily rainfall forecasts (IMD-MME) for up to 5-days lead-time. However, limited studies so far have evaluated these forecasts for analyzing floods in any Indian river basin. Most recently, the Long Short-Term Memory (LSTM) have emerged as the state-of-the-art machine learning models in rainfall-runoff simulations from a catchment. But, the possibility of the LSTM network-based models as the error-updating schemes integrated with a conceptual hydrological model (e.g., MIKE11-NAM-HD) for daily streamflow forecasting have not been explored in the literature. These daily streamflow forecasts along with the contribution from the reservoir releases may be used for forecasting the flood inundations in the downstream reaches. Further, with the evident increase in extreme flood risk in the tropical region, it is found that none of the studies have assessed and attempted to propose any adaptation measure to the flood risk as a function of crop damage due to flood inundation depth and duration under a changing climate in a dam-regulated Indian River basin. To address these issues, this study assessed the causal mechanism of recurring high floods in the Mahanadi River basin considering the retrospective and future projected climate change scenarios; developed a hybrid Copula–Enhanced Kohonen Self-Organizing Map (Cop-SOM) based bias-correction method for improving daily ensemble rainfall forecasts and compared its performance with the conventional Quantile Mapping (QM), Copula-based and enhanced Kohonen Self-Organizing Map (eKSOM) approaches; developed a short-to-medium range streamflow forecasting framework by integrating the standalone MIKE11-NAM-HD (MIKE) with a novel nested smoothing-based LSTM (sLSTM) and the recently developed Wavelet-based Nonlinear AutoRegressive neural network with eXogenous inputs (WNARX) error-updating sub-models; developed a flood inundation forecasting framework for the Mahanadi River delta considering reservoir outflow forecasts; assessed flood risk in the Mahanadi River delta in terms of agricultural production in a changing climate considering the most probable design floods; and recommended the potential rice varieties to be cultivated in the projected flood inundation areas in the Mahanadi delta as a probable flood adaptation strategy.

Accounting ranges of uncertainty from climate model simulations and the propagation of uncertainty across the numerical model chain, considering extreme rainfall as the covariate, floods in larger sub-catchments shows an increase in compound flood hazard in the projected period. Among the rainfall bias-correction techniques adopted herein, the hybrid Cop-SOM approach outperforms in correcting the highly biased daily raw IMD-MME rainfall forecasts with the least systematic errors. Overall, the sLSTM proves to be a robust error-forecasting model at 1–5 days lead-times with reliable reproduction of peak flows; and the MIKE-sLSTM framework forced with the Cop-SOM based bias-corrected rainfall forecasts has the lowest model prediction uncertainty. The MIKE FLOOD model is able to accurately simulate the inundation forecasts with reasonable accuracy up to 5-days lead-time in the delta region. Overall, the findings reveal an increased flood risk in the future projected scenarios in the Mahanadi River delta, which can be best-adapted with an alternate rice planning.

Keywords: *Bias-correction, Inundation modelling, Flood forecasting, Flood risk, River basin, Streamflow*