

Abstract

Coastal communities face rising compound-flood risk as extreme rainfall, streamflow, and cyclone-driven surges increasingly alter the sea-level rise, threatening lives and economies. In response, operational coastal flood management integrates continuous hydro-meteorological and oceanographic monitoring to issue real-time, multi-hazard warnings that alert stakeholders and enable timely flood management decisions. Expanding structural measures is costly and time-consuming; however, forecast-driven non-structural measures, such as streamflow forecasting, forecast-informed reservoir operation, inundation forecasting, and dynamic vulnerability mapping, offer effective and complementary approaches to managing compound coastal risk. The development of a streamflow forecasting tool becomes a challenging task due to the sophisticated nonlinear catchment response, varying crop management practices, and limited in situ data availability. For real-time streamflow forecasting with up to 10-days' lead-time, this study investigates the potential of the SWAT-pothole (PSWAT) module forced with the bias-corrected meteorological variables from the Global Forecasting System (GFS), wherein the error-updating is carried out using a novel Wavelet-based Bidirectional Long-Short Term Memory (WBiLSTM) for enhancing the streamflow forecasts by PSWAT. The results revealed that the novel PSWAT–WBiLSTM hybrid model is the best for reliable streamflow forecasts up to 8-days' and 9-days' lead-times in the Brahmani and Baitarani River basins, respectively. Subsequently, using the inflow forecast of the PSWAT–WBiLSTM, a reservoir module is developed, integrating two-stage (2SH) hedging optimized with Particle Swarm Optimization (PSO) with HEC-RAS-2D variants for downstream feedback, hereafter termed as the 2SH–PSO–HEC-RAS-2D framework. This framework could yield an average risk reduction of 22.28% lowering the absolute risk by 5.68% relative to the conventional static rule curve-based reservoir operation. Furthermore, to capture the storm surge induced by the tropical cyclone, a coupled ADCIRC+SWAN model is set up. The performance of ADCIRC+SWAN in predicting water surface elevations is excellent, with Nash–Sutcliffe Efficiency (NSE) values of 0.97–0.99 and errors within 8–18 cm. Subsequently, a comprehensive coastal flood inundation forecasting framework is developed, including real-time reservoir inflow forecasting, reservoir outflow forecasting based on rule curves, storm-tide forecasting using hydrodynamic and machine learning models, and flood inundation forecasting with a two-dimensional hydrodynamic model. The results demonstrate that the proposed framework could forecast the coastal inundation extents, with the fit-measures ranging from 87.45% to 39.57% at 1- to 8-days' lead times. Further, the flood vulnerability model is prepared with by integrating the forecast hazards (depth, velocity, rainfall intensity) over 1–8 days' lead-times, and other physical and socio-economic characteristics as the thematic layers, adhering to the United Nations Educational, Scientific and Cultural Organisation – Institute for Water Education (UNESCO–IHE) guidelines, which could detect the flood vulnerability hotspot well in advance.

Keywords: Flood forecasting; Reservoir operation; Inundation mapping; Storm-surge; vulnerability.