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ORIGINAL RESEARCH

Multi-step Ahead Urban Water Demand Forecasting Using Deep Learning Models

Bibhuti Bhusan Sahoo[1] · Banamali Panigrahi[2] · Trushnamayee Nanda[3] · Mukesh Kumar Tiwari[4] · Sovan Sankalp[5]

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Abstract

Accurate prediction of water demand in a city is crucial for the management of urban water distribution system. The current study aims to create adequate daily water demand forecasting models for the Canadian metropolis of London utilizing deep learning (DL)-based models. This study explores the potential of two stand-alone DL models for daily water demand modeling using a convolutional neural network (CNN) and the long short-term memory (LSTM) along with their hybrid CNN–LSTM model. Furthermore, a deep learning-based bi-directional LSTM model is introduced with CNN to predict daily water consumption in London as CNN–BiLSTM hybrid model. Daily water consumption data for the years 2009 to 2020 are used for the development and assessment of the predictive models. These stand-alone and hybrid models have been developed with specified input lags of daily water demand and verified for daily water demand prediction. The performance of the developed hybrid models was compared with other well-established DL-based stand-alone models. The model out-comes during the training, validation, and testing phases were assessed using statistical metrics such as the mean absolute error (MAE), Nash–Sutcliffe coefficient (NSE), correlation coefficient (r), Scatter Index (SI), Mean Bias Error (MBE), and Discrepancy Ratio (DR). The stand-alone models captured the observations very well during training and testing which is obvious at 1-day ahead. Moreover, at 7 days and 15 days ahead those models, except the stand-alone CNN, closely repro-duced the pattern in daily water demand. Among the hybrid models, the outperforming CNN–BiLSTM model produced 1-day to 15-day multi-step ahead forecasting with performance metrics in the following ranges: MAE = 0.245–2.541 ML/day, NSE = 99.830–84.843% and r = 0.999–0.921 during the testing period. The uncertainty analysis has been performed which advocates the superiority of the CNN–BiLSTM model showing the forecasts bands with 88–90% observations within the 90% confidence interval (CI). Overall, the outcomes supporting the CNN–BiLSTM is to be considered as a promising deep learning procedure for accurate forecasting of urban water demand in any city globally.

Keywords Water demand · Deep learning · Urban water · Neural network models · Forecasting

✉ Banamali Panigrahi
bap654@usask.ca

Bibhuti Bhusan Sahoo
bibhuti5000@gmail.com

Trushnamayee Nanda
nanda.trushnamayee@gmail.com

Mukesh Kumar Tiwari
tiwari.iitkgp@gmail.com

Sovan Sankalp
sovan.sankalp@cutm.ac.in

[1] Department of Agricultural Engineering, Centurion University, Paralakhemundi, Odisha, India

[2] Toxicology Center, University of Saskatchewan, 44 Campus Drive, Saskatoon, SK S7N 5B3, Canada

[3] Soil and Water Conservation, Directorate of Soil Conservation and Watershed Development, Bhubaneswar, Odisha 768004, India

[4] College of Agricultural Engineering and Technology, Anand Agricultural University, Godhra 389001, India

[5] Department of Civil Engineering, Centurion University of Technology and Management, Bhubaneswar, Odisha 761211, India

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