

HEC-HMS AND MACHINE LEARNING APPROACHES FOR STREAMFLOW FORECASTING: A COMPARATIVE STUDY

H.H.U. Manjitha, D.M.C.A. Perera *

Department of Civil Engineering, University of Moratuwa, Moratuwa

Accurate river discharge prediction is crucial for effective water resources management, flood forecasting, and disaster preparedness. While physically based hydrological models such as the Hydrologic Engineering Centre - Hydrologic Modelling System (HEC-HMS) are widely used because they explicitly represent catchment processes, they often require extensive datasets, involve complex parameterisation, and demand intensive calibration, which limits their applicability in data-scarce regions. In contrast, Machine Learning (ML) techniques provide a data-driven alternative capable of capturing complex, non-linear relationships of the rainfall-runoff process without explicit physical assumptions.

This research presents a comparative analysis of HEC-HMS and four ML algorithms (Artificial Neural Networks (ANNs), Long Short-Term Memory (LSTM) networks, Random Forest (RF), and XGBoost), for streamflow prediction in two contrasting Sri Lankan River basins: the flood-prone Kelani River Basin in the wet zone and the irrigation-influenced Malwathu Oya Basin in the dry zone. Daily precipitation and discharge data (1990-2020 for Kelani; 2006-2018 for Malwathu Oya) were used for model calibration and validation. HEC-HMS was configured with the Soil Moisture Accounting, Clark Unit Hydrograph, and Muskingum routing methods, whereas ML models utilised rainfall and lagged discharge as input variables. Model performance was evaluated using multiple statistical indicators, including Nash–Sutcliffe Efficiency (NSE), Kling–Gupta Efficiency (KGE), Root Mean Square Error (RMSE), Percent Bias (PBIAS), and R^2 .

Results indicate that ML models consistently outperformed HEC-HMS in both basins. In the Kelani basin, LSTM achieved the highest accuracy (NSE = 0.89, KGE = 0.90), effectively reproducing flood peaks, whereas HEC-HMS exhibited moderate performance (NSE = 0.81). In the Malwathu Oya basin, LSTM and XGBoost performed similarly well (NSE $\approx$ 0.80), successfully capturing irrigation-driven variation and low-flow conditions, while HEC-HMS showed weaker performance (NSE = 0.49, PBIAS = 15.82).

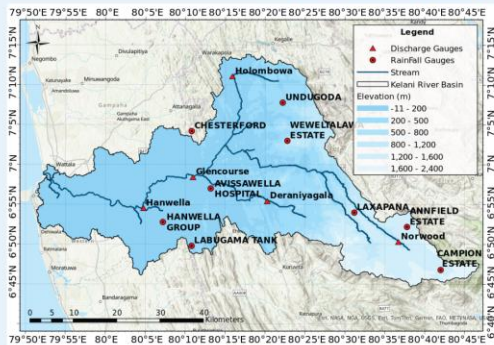
The findings highlight the adaptability of ML methods, particularly LSTM, in capturing diverse hydrological regimes, while showing the value of process-based models like HEC-HMS in understanding physical mechanisms. The study recommends developing hybrid modelling frameworks that combine process-based strengths of HEC-HMS with the predictive power of ML to improve flood forecasting and water management in tropical, data-scarce regions.

Keywords: Data-driven models, Rainfall-runoff modelling, Streamflow prediction, Tropical river basins, Water resource management

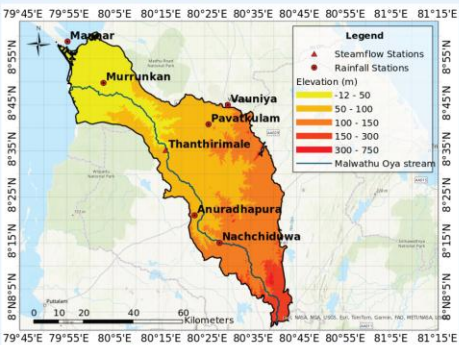
* Correspondence: chamalp@uom.lk

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A Comparative Study in Sri Lankan River Basins



Kelani River Basin (Wet Zone)



Malwathu Oya Basin (Dry Zone)

Characteristics	Kelani Basin	Malwathu Basin
Area	2,292 km ²	3,245 km ²
Climate	Tropical wet zone	Semi-arid dry zone
Annual Rainfall	3,450 mm (avg)	1,000–1,200 mm
Flow Pattern	Perennial, fluvial floods	Seasonal, irrigation-dependent

Data Collection & Processing

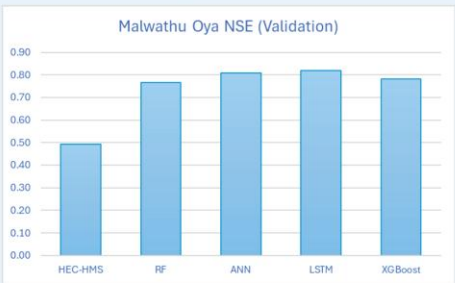
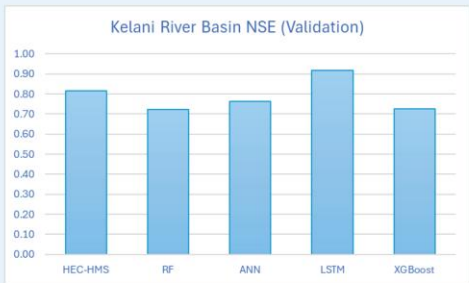
- Rainfall Data
- Streamflow Data

Model Implementation

- HEC-HMS
- Random Forest
- ANN
- LSTM
- XGBoost

Performance Evaluation

- NSE
- RMSE
- R²
- KGE
- PBIAS



- LSTM showed superior performance across both basins (NSE: 0.89 in wet zone, 0.80 in dry zone)
- HEC-HMS performed significantly better in wet zone (NSE: 0.81) than dry zone (NSE: 0.49)
- Machine learning models consistently outperformed process-based HEC-HMS in seasonal prediction

Manjitha H.H.U. (2025), University of Moratuwa