ENHANCING STREAMFLOW PREDICTION IN SRI LANKAN RIVER BASINS USING AI MODELS: A COMPARATIVE STUDY OF WET AND DRY ZONES

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Artificial Intelligence (AI) techniques have gained significant attention in recent years for their application in various engineering domains, including hydrology. Groundwater modelling, streamflow prediction, precipitation forecasting, temperature forecasting, and time series generation for rainfall are some of the hydrological applications that have benefited from AI techniques. In Sri Lanka, water resource management is challenging due to the country's geographical characteristics, seasonal rainfall patterns, and growing water demands. Traditional methods used in water resource management have limitations and rely on complex parameters, which often result in less accurate predictions of rainfall-runoff, flood events, and drought conditions, impeding effective water resource management. To enhance water resource management practices in Sri Lankan River basins, AI methodologies were integrated into hydrological modelling.

Two river basins were chosen as representatives of the wet and dry zones in Sri Lanka: the Ellagawa sub-basin from the Kalu River basin for the wet zone, and the Thanamalwila sub-basin from Kirindi Oya basin for the dry zone, covering the period from October 1, 2000, to September 30, 2011. The pivotal recurrent neural network (RNN) architectures such as Long Short-Term Memory (LSTM) and Gated Recurrent Unit (GRU) are highly effective for modelling time series data, especially when it comes to streamflow prediction. These models are excellent at capturing temporal dependencies, which is significant for streamflow as it depends on previous data and weather. In this study, both the physically-based semi-distributed HEC-HMS hydrological model and AI models such as RNN-LSTM and RNN-GRU were applied to evaluate their predictive capabilities in streamflow forecasting. The performance of these models was assessed using objective criteria including Nash-Sutcliffe Efficiency (NSE), Mean Ratio of Absolute Error (MRAE), and the coefficient of determination (R^2).

The observed and predicted streamflow hydrographs and flow duration curves (FDC) were generated to evaluate model goodness of fit and time series graphical comparability. The study findings indicate that the LSTM model is superior to both the GRU and HEC-HMS models in predicting streamflow, with an MRAE of 0.42 and NASH of 0.82 for the LSTM model in wet zone river basins. The LSTM algorithm used the best values of R^2, which were 0.88 and 0.87 for the testing and training phases, respectively. The proposed model may be used to develop other basins in the wet zone. However, for the Thanamalwila sub-basin, the results of both AI and physical-based models were poor, likely due to inaccurate input features and inherent mismatches between rainfall and streamflow. Better input features are essentially required to improve the model training and simulation process. Therefore, the integration of AI techniques presents an opportunity for Sri Lanka to overcome existing limitations in hydrological modelling and enhance its resilience to water-related challenges. By embracing innovative approaches and leveraging available data, Sri Lanka can strengthen its capacity for water resource management and adaptation to climate change impacts, ultimately fostering sustainable development and resilience in the face of evolving environmental conditions.

Keywords: AI techniques, GRU, Kalu river basin, Kirindi Oya basin, LSTM, RNN

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Aim & Objectives

Aim

To evaluate how Artificial Intelligence techniques can be applied effectively within Sri Lankan river basins to enhance water resource management.

Objectives

To gather data, conduct a detailed investigation of the characteristics of Sri Lankan River basins, and develop a traditional or AI-based model for predicting missing data

To develop AI-based models for streamflow prediction in two river basins, covering both dry and wet zones

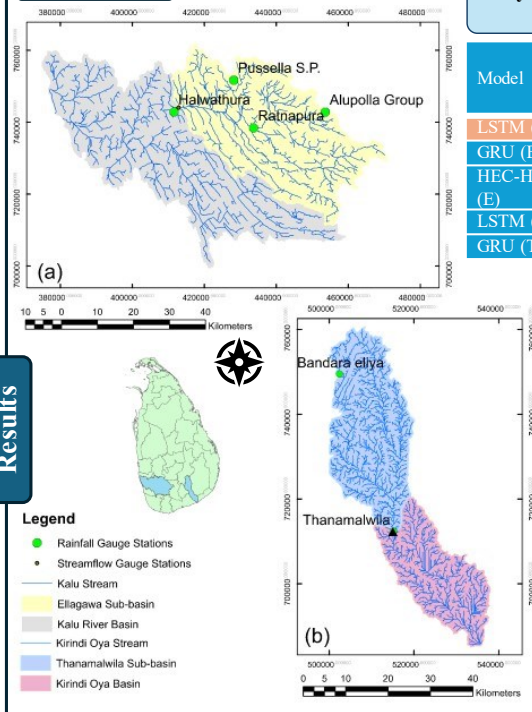
To compare the performance of AI models with traditional hydrological models to verify the results gathered from AI models

Methodology

Two River basins from Wet and Dry zone → Streamflow, Precipitation & Temperature Data → Training (2000-2008) / Testing (2008-2011) → HEC-HMS / RNN-LSTM / RNN-GRU → Streamflow Simulation

Results

Study Area

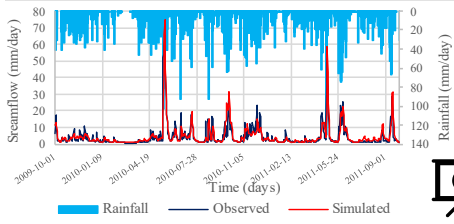


(a) Ellagawa sub-basin in wet zone (1,414 km ^{2})
(b) Thanamalwila sub-basin in dry zone (675 km^2)

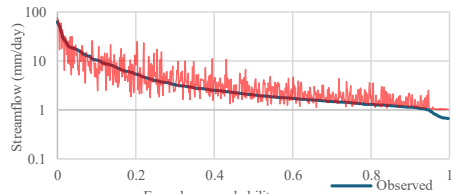
Hydrological Model Performance in Ellagawa & Thanamalwila

Model	Training Period			Testing Period		
	NSE	MRAE	R^2	NSE	MRAE	R^2
LSTM (E)	0.76	0.39	0.87	0.82	0.42	0.88
GRU (E)	0.63	0.22	0.83	0.81	0.32	0.87
HEC-HMS (E)	0.73	0.37	0.86	0.80	0.40	0.86
LSTM (T)	0.63	2.47	0.81	0.42	2.24	0.56
GRU (T)	0.34	0.79	0.62	0.30	1.42	0.45

Unsatisfactory results in Kirindi Oya basin



Hydrograph forEllagawa sub-basin (LSTM model)- Testing



FDC curve Ellagawa sub-basin (LSTM model)- Testing