

ARTIFICIAL INTELLIGENCE TECHNIQUES IN BASIN HYDROLOGICAL AND MATERIAL FLOW MODELLING: INSIGHTS FROM DRY AND WET ZONE RIVER BASINS IN SRI LANKA

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Water resource management has become a serious global challenge due to climate change, urbanization, and climate-induced irregular rainfall patterns. Traditional hydrological models, which depend on physical laws and long-term records, often struggle in regions with limited or inconsistent data. These models also face difficulty in capturing the non-linear, complex behaviors of real-world hydrological systems. Sri Lanka, with its diverse climate and topography, is especially affected. The Kelani River Basin in the wet zone and the Malwathu Oya Basin in the dry zone face unique and different water-related problems, such as pollution, flooding, and drought. Artificial Intelligence (AI) provides a novel solution that can handle data gaps and complex relationships. This research aims to study how effective different AI techniques are in predicting streamflow, filling missing rainfall data, and modelling nutrient levels in Sri Lankan river basins. The main objective of this study is to assess the suitability of AI models for improving hydrological and material flow analysis in Sri Lankan river basins.

Daily rainfall and streamflow data (1990–2019) and monthly water quality data were collected and cleaned using standard methods like single and double mass curves. Models used in this study, suggested by the literature, include Multiple Linear Regression (MLR), Random Forest (RF), XGBoost, Long Short-Term Memory (LSTM), and Time Series Transformer (TST), which was implemented using the Python programming language. Data were split into 80% for training and 20% for testing. For rainfall imputation, artificial gaps of 10% and 20% were created to test model accuracy. Nutrient modelling used monthly average rainfall, streamflow, and water quality parameters such as pH, turbidity, dissolved oxygen, and temperature. Model performance was evaluated using Nash–Sutcliffe Efficiency (NSE), Mean Absolute Error (MAE), Root Mean Square Error (RMSE), and Pearson correlation coefficient (r).

For streamflow prediction, LSTM gave the best results in the Kelani Basin (test NSE = 0.71), while XGBoost overfitted the training data. In the Malwathu Oya Basin, simpler models like MLR and TST performed better, achieving test NSE above 0.80. The RF model proved to be the most reliable method for imputing missing rainfall data in both basins. While MLR showed slightly higher accuracy in some cases, RF gave more stable results across different deletion levels. However, here using complex models did not bring much improvement over simple statistical ones. Nutrient modelling was more challenging. RF showed promise for predicting chloride levels (test NSE = 0.40), but nitrate predictions were poor in all models (NSE < 0.15). And, identified a weak correlation with nutrient flow and hydrological inputs.

In conclusion, AI techniques are highly useful for improving streamflow prediction and filling data gaps. However, predicting nutrient concentrations needs more input variables, such as land use and pollution data. Future research should explore hybrid models that combine AI with physical processes for more accurate and reliable water resource management.

Keywords: Machine Learning, Nutrient modelling, Rainfall imputation, Streamflow prediction, Transformer models

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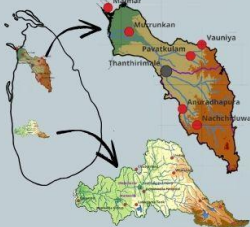
Problem Statement

The existing traditional models have limitations which Artificial Intelligence can overcome. However these are underexplored in Sri Lanka.

Specific Objectives

- In Sri Lankan river basins, Assess the applicability of AI
- to predict streamflow
 - to predict material flow data
 - to impute missing rainfall data

STUDY AREA



Kelani River - Wet Zone

- 30-year RF (10 stations) and SF Data (1 station).
- WQ Data from 2003 to 2020.

Malwathu Oya - Dry zone

- 12-year RF (6 stations) and SF Data (1 station).

Study Area, Models, Inputs and Methodology were selected based on Literature



INPUTS

- Rainfall Data (RF)
- Streamflow Data (SF)
- Water Quality Data (WQ)

PROCESSES

- Predicting Streamflow [Daily]
- Predicting Nutrient Flow [Monthly]
- To impute Missing Rainfall Data [Daily]

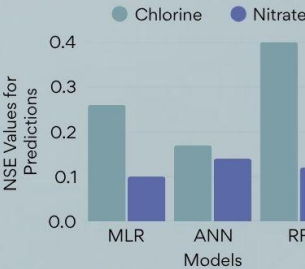
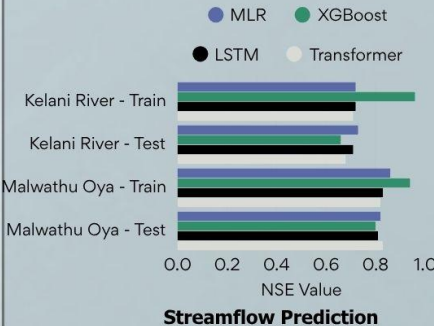
MODELS

- Long Short Term Memory (LSTM)
- Artificial Neural Networks (ANN)
- Multiple Linear Regression (MLR)
- Multi Layer Perceptron (MLP)
- Random Forest (RF)
- Extreme Grade Boost (XGBoost)
- Time Series Transformer Models

CONCLUSIONS

- ✓ AI models performed slightly well but not significantly better than statistical models in imputing missing rainfall data.
- ✓ For streamflow prediction, all the models have shown promising results, Transformers predicted slightly lower results.
- ✓ There is a relationship between elevation and rainfall patterns in Kelani River Basin
- ✓ Nutrient prediction models performed poorly because nutrient values are instantaneous, and using only average hydrological inputs smooths out short-term fluctuations, resulting in low predictive accuracy and not reflecting long-term conditions.

RESULTS



Model	IDW			
	0.65	0.66	0.64	0.72
	0.68	0.67	0.58	0.66
	0.67	0.66	0.57	0.59
KRB 20% KRB 10% MOB 20% MOB 10% Basin and Deletion Rate				

FUTURE WORK

- ◆ Hybrid models should be tested by combining AI with physics process based models.
- ◆ More inputs should be evaluated like remote sensing data, land cover indices.