Rainfall-Runoff modelling using hydrological models and soft computing techniques

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by

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Chapter 6

SUMMARY AND CONCLUSIONS

1.1 SUMMARY

Rainfall-runoff modelling is basic to design of a wide variety of hydraulic structures, environmental impact assessment, irrigation scheduling, flood forecasting and augmentation of runoff records, pollution abatement, and watershed management and so on. To this end, several rainfall-runoff models were developed to mimic the process from plot to catchment scale. However, research is still continuing largely by linearizing different components of the rainfall-runoff process. Observations based on review of literature largely motivated to undertake this research work. There exists a need for simple and accurate techniques of runoff prediction for the M.H. Halli station of Hemavati River basin.

The study was carried at with the following specific objectives;

a) To estimate model errors in the computational runoff by using posterior fire-breathing network,
b) To estimate the infiltration rate by the prophetic multilayer network is directly considering the relationship between infiltration and soil moisture through a collection of parsimonious computational parameters
c) To predict rainfall and calculates the velocity of runoff on steep slopes by utilizing well-ordered selective genetic algorithm
d) To estimate discharge through the hydrological and data driven models.
e) To compare hydrological and data driven models for discharge prediction (HEC-HMS and RF).

A summary of the research work and the conclusions arrived at are presented below.

1.2 Rainfall prognostic artificial model framework

Despite the progress made in recent years, modeling hydrological reactions to rainfall prediction remains a complex task in runoff modeling. Thus, the presented paper effectively introduced a Rainfall prognostic artificial model framework for the prediction of rainfall. The framework applied a posterior fire breathing network to estimate model errors with random noise to reduce the uncertainty. Further to regulate the infiltration rate the system suggested a prophetic multilayer network that analyses the runoff levels with the soil moisture in urban and rural areas. In addition, to tackle the numerical challenge, the model integrates a well-ordered selective genetic algorithm to forecast different bend zones at low water depths on steep slopes. As a result of the rainfall model, everyday rainfall can be accurately anticipated to avoid environmental problems. Experimental results reveal that the framework surpasses existing runoff models with a better infiltration rate of 1.5cm/hr, runoff level of 0.05cm, and achieved velocity of 0.45mm, and has the highest prediction range of 12-20 mm with subjective results.

1.3 Runoff Prediction using Hydrological modelling

Hydrological studies are important and necessary for water and environmental resources management. Demands from society on the predictive capabilities of such study and analysis of hydrological parameters are becoming higher and higher, leading to the need of enhancing existing research theories and even on developing new theories. The study has been conducted in the MH. Halli station of Hemvati River, Karnataka state, India, which is an important river basin in India from Hydropower, perspective. The following conclusion can be drawn from the analysis.

i. The HEC-HMS and SWAT hydrological simulation catchment model has been calibrated (2003 – 2010) and validated (2010 – 2017) at the MH Halli station.
ii. The coefficient of determination (R^2), RMSE and MAE of model performance criterion are used to evaluate the model applicability.
iii. The HEC-HMS model provided the highest R^2 and the lowest MAE and RMSE in testing data sets. Where the calculated value of R^2 has found 0.854 for calibration period and 0.791 for validation period.
iv. The results of the SWAT model accuracy evaluation has suggested that the overall values of R^2 is within the criteria " very good" (0.94), NSE is "very good" (0.88) (88% of the simulated discharges are similar to the discharges observed) and RMSE and d is "good" (47.71 and 0.98).

1.4 Runoff Prediction using Soft Computing Technique

Runoff prediction is a crucial aspect of hydrological modeling and water resource management. Soft computing techniques, such as Artificial Neural Networks (ANN), Random Forest (RF), and M5P, offer a more flexible and adaptive approach compared to traditional statistical methods for predicting runoff. These techniques can handle complex, non-linear relationships between various hydrological variables, making them well-suited for modeling the uncertainties inherent in runoff prediction. By leveraging the capabilities of soft computing, researchers and practitioners can develop more accurate and reliable models for runoff forecasting, which is vital for flood management, irrigation planning, and environmental conservation. The following conclusion can be drawn from the analysis.

i. The RF and M5P models have been calibrated (2003 – 2010) and validated (2010 – 2017) at the MH Halli station.
ii. The coefficient of determination (R^2), RMSE, MAE and d of model performance criterion are used to evaluate the model applicability.
iii. The M5P model provided the highest R^2, NSE and d and lowest RMSE in the calibration dataset.
iv. The RF model provided highest R^2 and lowest RMSE and MAE in the calibration dataset.
v. The M5P and RF both models performed outstanding during the calibration dataset with (R^2=0.97, NSE=0.91, d=0.99 and RMSE= 29.12) and (R^2=0.99, MAE=0.16, and RMSE= 12.61) than the validation dataset (R^2=0.92, NSE=0.76, d=0.96 and RMSE= 37.02) and (R^2=0.32, MAE=25.15, and RMSE= 87.85) correspondingly.

1.5 Comparison between Hydrological modelling and Soft Computing Technique

The comparison between hydrological modeling and soft computing techniques is essential for guiding researchers, hydrologists, and water resource managers in selecting appropriate methods for their specific applications. Understanding the strengths and limitations of each approach allows for informed decision-making based on the nature of the hydrological system, data availability, and the objectives of the study. Hydrological modeling, rooted in physical principles, provides a mechanistic understanding of water processes but may face challenges in handling complex relationships. Soft computing techniques, being data-driven and adaptable, excel in capturing intricate patterns but might lack the transparency associated with traditional models. A thorough comparison aids in identifying the most suitable methodology, potentially leading to more accurate and reliable predictions in water resources management, flood forecasting, and other hydrological applications. The following conclusion can be drawn from the analysis.

i. The hydrological model and soft computing techniques has been compared for the discharge forecasting.
ii. The models have been calibrated (2003 – 2010) and validated (2010 – 2017) at the MH Halli station.

iii. The coefficient of determination (R^2), RMSE, MAE and d of model performance criterion are used to evaluate the model applicability.
iv. While comparing HEC-HMS and RF model, the RF model performed outstanding than the HEC-HMS model. The RF provided the highest R^2 and lowest RMSE and MAE.
v. While comparing SWAT and M5P model, the M5P model performed outstanding than the SWAT model. The M5P provided the highest R^2, NSE, d and lowest RMSE and MAE.
vi. Overall, the soft computing techniques has been performed outstanding compared to the hydrological model.

1.6 Major research contributions

This study makes several significant contributions to the field of hydrological modeling and data-driven analysis. Firstly, the integration of hydrological models such as SWAT and HEC-HMS with advanced soft computing models like Random Forest (RF) and M5P represents a novel approach to improving the accuracy of discharge predictions. The combination of physics-based models and data-driven techniques harnesses the strengths of both paradigms, offering a more robust and flexible framework for understanding complex hydrological processes. Secondly, the study provides insights into the comparative performance of these models, shedding light on their strengths and weaknesses in different scenarios. Additionally, the application of the M5P model tree within the Weka software highlights the practical implementation of advanced algorithms for hydrological analysis.

1.7 Importance of the Study:

The significance of this study lies in its potential to enhance our understanding of discharge prediction, a critical aspect of water resource management. By integrating hydrological and soft computing models, the research not only contributes to the advancement of modeling techniques but also addresses the challenges associated with predicting discharge in diverse and dynamic environmental conditions. The findings of this study can inform decision-makers, water resource planners, and environmental scientists, providing valuable insights for sustainable water management practices.

1.8 Scope for Future Research Work:

The study opens avenues for future research in several directions. Firstly, there is potential for further refinement and optimization of the integrated modeling approach by exploring different soft computing algorithms or hybrid models. Investigating the sensitivity of model performance to various input parameters and exploring new data sources for model calibration are also areas for improvement. Additionally, considering the impact of climate change on hydrological processes and extending the study to different geographic regions can broaden the applicability of the proposed modeling framework. Future research could also focus on real-time applications and the development of decision support systems for proactive water resource management. Overall, the study lays a foundation for ongoing research aimed at advancing the accuracy and applicability of hydrological models in a rapidly changing environmental landscape.