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EXTENDED ABSTRACT

Daily Rainfall – Runoff Modeling of Darreh-Rud River in Ardabil Province, Iran

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Introduction

Rainfall- runoff is one of the most complicated hydrological processes that is affected by various physical and hydrological variables. Therefore, understanding and predicting runoff formation processes and their transfer to the outlet point of the watershed is one of the most important issues of hydrological sciences (Salajegheh et al., 2009). Botsis et al., (2011) simulated daily rainfall-runoff of a catchment in the California, USA. They compared the performance of SVM with three types of kernel function with ANN. Finally, the SVM had a more accurate simulation of rainfall-runoff. Nourani et al., (2009) applied the hybrid of wavelet-ANN to model rainfall-runoff of Lighvan-Chay basin in Iran. The results showed that the proposed model is capable to predict long-term and short-term rainfall events due to the use of the time series with multiple scales as input layer of ANN. Darreh-rud river as the most important branch of Aras border region in Iran, is one of the main rivers of Ardabil province and the main source of water supply in different parts of the province. On the other hand, the Emarat reservoir dam is under construction on the river. Therefore, ANN, WNN, GEP and LS-SVM models were evaluated for estimating the inflow of Emarat dam (located on Darreh-rud river, Ardabil province).

Methodology

In the present study, daily runoff and rainfall data from the Moshiran hydrometric station located in river and the upstream of Emarat dam for a period of 26 years (i.e. 1988-2014) was used. In order to select the appropriate combination of the input variables of the models, statistical tests were used and the partial auto-correlation coefficients of discharge and cross-correlation values between rainfall-discharge variables were calculated. The correlation values between the discharge, rainfall and related delays are presented in Table (1). In the table, the R and Q variables indicate the measured values of rainfall and discharge at Moshiran hydrometric station, respectively, and the t-index is the current time step. Considering the cross and significant correlation between input-output variables, different input patterns were used to estimate the daily runoff of the Darreh-rud river according to Table (2).

Table 1- The correlation values between rainfall-discharge variables

	Q_{t-1}	R_t	R_{t-1}	R_{t-2}
Q_t	0.916	0.107	0.126	0.115

Table 2- The structure of patterns used in this study

Pattern No.	*Input combination*	*output*
1	R_t	Q_t
2	R_{t-1}, R_t	Q_t
3	R_{t-2}, R_{t-1}, R_t	Q_t
4	Q_{t-1}, R_t	Q_t
5	Q_{t-1}, R_{t-1}, R_t	Q_t
6	Q_{t-1},R_{t-2}, R_{t-1}, R_t	Q_t

Results and Discussion

In the Tables (3-6), the statistical measures of the performance for the applied models in the present study are reported for the train and test stages based of different patterns. As can be seen from Tables (5-8), for GEP model, in the pattern No. 5 and for other models, in the pattern No. 4 provide the best performance. Pattern No. 4 requires a smaller number of inputs compared to other patterns, and its important advantage is to reduce the runtime of the models and their complexity. Therefore, the discharge of the river in the current time generally is influenced by its value on the previous day and the rainfall in the current time. It is noted that in all models, patterns No. 1-3 present poor results, which suggests that in the Darreh-rud watershed, using only rainfall data cannot provide proper estimation of run-off. Comparison of the results of different models using the best pattern indicates that the WNN model with the highest correlation coefficient (R = 0.982), the lowest root mean square error (RMSE = 1.589), and the NS equal to 0.905 in the validation step has shown better performance than other models in river flow estimation. In addition, the statistical criteria related to the training stage of the mentioned model are closer to the desired values. This is while the performance of other models is roughly the same. On the other hand, the NS values of training and validation phases of all the models applied in the present study are higher than 0.8 through optimal patterns, indicating their acceptable performance. The results showed that the error of the models in the estimation of the maximum discharge values was approximately the same and the least error (i.e. 25.97%) was related to the WNN model.

Table 3- The statistical measures of LS-SVM for diffrent patterns

Pattern No.	*Train*			*Test*		
	R	*RMSE* (m^3/s)	*NS*	*R*	*RMSE* (m^3/s)	*NS*
1	0.100	12.299	0.010	0.044	7.814	-0.017
2	0.137	12.245	0.018	0.56	7.833	-0.032
3	0.182	12.155	0.033	0.078	7.867	-0.053
4	**0.928**	**4.586**	**0.862**	**0.933**	**1.938**	**0.859**
5	0.930	4.159	0.866	0.929	2.009	0.849
6	0.930	4.520	0.866	0.930	1.991	0.851

Table 4- The statistical measures of WNN for diffrent patterns

Pattern No.	*Train*			*Test*		
	R	*RMSE* (m^3/s)	*NS*	*R*	*RMSE* (m^3/s)	*NS*
1	0.238	12.027	0.056	0.131	8.060	-0.105
2	0.251	12.017	0.062	0.132	8.008	-0.124
3	0.336	11.639	0.113	0.134	8.111	-0.125
4	**0.974**	**2.809**	**0.948**	**0.952**	**1.589**	**0.905**
5	0.972	2.868	0.946	0.942	1.740	0.886
6	0.974	2.841	0.947	0.947	1.728	0.889

Table 5- The statistical measures of GEP for diffrent patterns

Pattern No.	*Train*			*Test*		
	R	*RMSE* (m^3/s)	*NS*	*R*	*RMSE* (m^3/s)	*NS*
1	0.175	12.139	0.030	0.070	7.463	-.017
2	0.209	12.052	0.043	0.095	7.790	-0.028
3	0.127	12.229	0.016	0.015	7.706	-0.035
4	0.916	4.939	0.839	0.928	1.984	0.853
5	**0.927**	**5.029**	**0.833**	**0.930**	**1.931**	**0.860**
6	0.780	1.410	0.834	0.928	1.936	0.859

Table 6- The statistical measures of ANN for diffrent patterns

Pattern No.	*Train*			*Test*		
	R	*RMSE* (m^3/s)	*NS*	*R*	*RMSE* (m^3/s)	*NS*
1	0.130	12.254	0.017	0.077	7.772	-.018
2	0.240	12.000	0.057	0.087	7.770	-0.042
3	0.223	12.050	0.049	0.127	7.763	-0.055
4	**0.930**	**4.350**	**0.875**	**0.930**	**1.911**	**0.860**
5	0.930	4.630	0.859	0.930	1.934	0.861
6	0.928	4.610	0.861	0.930	1.932	0.861

Conclusions

In the present study, the efficiency of different intelligent models was investigated in daily river flow estimation of Darreh-rud river. In this regard, a long period of daily discharge and rainfall (i.e. 26 years) at the Moshiran hydrometric station located on the river were used. In order to simulate the streamflow, six different patterns were considered. For all models, the accuracy of daily discharge estimation was improved by combining rainfall and discharge variables. As the highest accuracy of the models in the prediction of run-off was provided with one lag of run-off and rainfall. This indicates the high impact of run-off in the Darreh-rud river from the previous day of run-off and current day of rainfall. In this regard, the effect of the discharge from the previous day of run-off was more than the rainfall, and necessarily increase the amount of rainfall does not increase the discharge. The values of correlation coefficients (Table 1) also statistically indicate the lower influence of discharge from rainfall variable. Statistical analysis showed that the models used in this study have acceptable performance in daily estimation of Darreh-rud river. Furthermore, due to the higher accuracy of the WNN model, we can use this model as an efficient and reliable tool to estimate the streamflow in the studied region. Also, the results indicate that the performance of the models for predicting maximum discharge is somewhat similar, while the WNN model has a better performance in this regard.

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