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Runoff Prediction under Climate Change: Artificial Neural Network Approach

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Abstract— **Nowadays climate change phenomena is identified as an environmental issue all over the world. In result of human industrial activities, measurements of green house gases are increased which leads to global warming and its sequences. In the last decades, concerns about average temperature rising and its potential destructive results were noted. Also water resources which is one of the most effective in human life, are not in security. So to efficient management, it is worthy to calculate the climate change impacts on important parameters in water resources such as runoff. But rainfall-runoff models are complex and in other hand data mining models had impressive progress in recent years and are helpful to predict runoff. Genetic programming (GP), artificial neural network (ANN) and support vector machine (SVM) are such data mining tools that have many uses in various fields. In the present paper, climate precipitation and temperature are estimated by HadCM3 AOGCM and statistic downscaling and then by using ANN runoff was calculated in Aydoghmoush basin, Iran. The result shows that ANN could be an efficient and simple tool to this purpose.**

Keywords— climate change, runoff prediction, artificial neural network.

I. Introduction

Although human growth in industry has useful sequences to live simply but has desructive impacts on our environment. In other words, climate change or global warming is penalty of industrialization. So this phenomena and its results have been noticed by organizations and scientists all over the world. Intergovernmental Panel in Climate Change (IPCC) in 1988 was established by World Meteorological Organization (WMO) and United Nation Environment Program (UNEP) in order to explore climate change and the sequences. Average temperature rising, rising of water level in free seas and melting of polar ices are a few climate change impacts. Climate change impacts have been investigated in many articles. Fapeng et al. (2013) has investigated climate change impacts on precipitation and runoff. They showed that annual precipitation and runoff will increase. In this paper, its impacts on runoff is checked.

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Rainfall-runoff model are used to estimate runoff. Conceptual models require a lot of data to calculate runoff. But data mining models e.g. artificial neural network (ANN) are simple. They can distinguish the mathematical relationship between inputs and target parameters so then by receiving new inputs, they have the ability to guess the corresponding output. Predicting floods by using ANN (Elsafi, 2014) and river water quality modeling by using ANN (Sarkar and Pandey,2015) are examples of using ANN in water resources field.

In order to predict runoff under climate change in the present paper, at first effective hydrologic parameters on runoff means downscaled participation and temperature are found by HadCM3 AOGCM and then the runoff is predicted by ANN. ANN is a data mining tool which is a smart system and could realize the complicated rules between parameters in training process. After training, ANN receives new inputs and presents the corresponding output. In this paper, monthly precipitation and temperature are inputs and monthly runoff is target of ANN.

II. Methodology

A. *Climate model*

According to IPCC's definition of climate change, this phenomena is a significant statistical change of climatic parameters for a long period which is more than a decade. Based on various criteria, IPCC has presented different greenhouse gas emissions scenarios. In this paper, period 1986-2000 is considered as baseline years, precipitation and temperature parameters for period 2026-2039 are calculated by HadCM3 AOGCM under A2 emission scenario. Monthly average precipitation and temperature under climate change for the period 2026-2039 are shown in Fig. 1 and Fig. 2, respectively. (Ashofte et al., 2013).

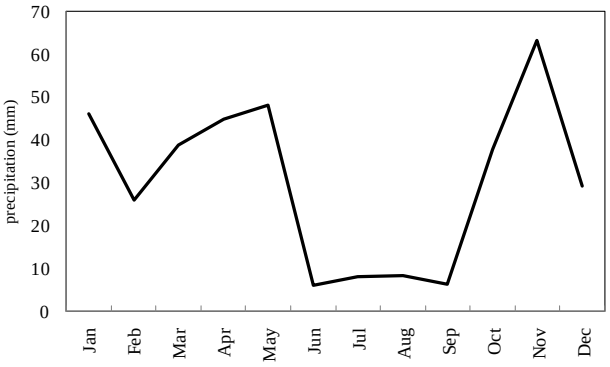

Figure 1. Monthly average precipitation under climate change

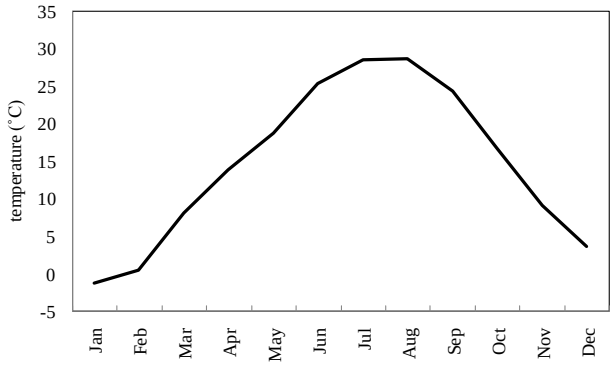

Figure 2. Monthly average temperature under climate change

B. *Artificial Neural Network (ANN)*

ANN is a data processing system which is based on human brain. Data processing is done by a lot of small processors as a integrated network which works in parallel to solute a problem. By help of programming, data structure is designed which is called Neuron. Then by creating a network between neurons and apply a learning algorithm, network is trained. In general, ANNs are non-linear learning math. In general, an ANN has 3 sections: 1) input layer; which get the initial data, 2) hidden layer(s); which determines the weights and the relationships between neurons and allows to pass through a sigmoid function and 3) output layer; which presents the corresponding output ANN performance is shown schematically in Fig. 3.

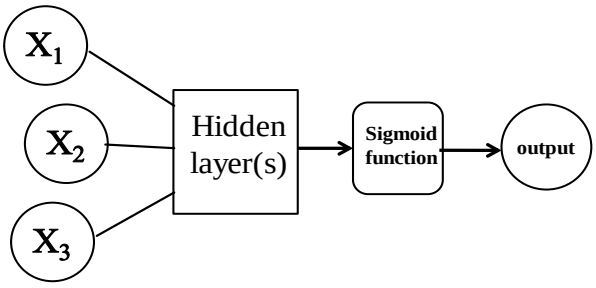

Figure 3. schematic of an ANN's performance

As is shown in the Fig. 3, at first inputs enter to the model. Then, with the aim of minimizing the amount of error simulation, weight and bias can be calculated. The results are transferred through a non-linear function and finally output is achieved. There are several algorithms as training models and calculating of weight and bias but the most well-known one is Levenberg-Marquardt (LM) which is a optimization algorithm with aim to minimizing the square error. In fact, ANN training is adjustment of communication weights between neurons for different examples in order to converge to desired output.

In this paper, in order to runoff predict under climate change, an ANN is used which has 2 hidden layers and each of them has 2 neurons.

III. Formulation of the prediction model

In this step, monthly normalized precipitation and temperature parameters in the period 2026-2039 are used to monthly predict. The normalization equation is shown by (1):

$$x_{norm}=\frac{x-x_{min}}{x_{max}-x_{min}} \quad (1)$$

where x_{norm}= the normalized parameter; x=real amount of parameter before normalization; x_{min} and x_{max} = the minimum and maximum of the parameter before normalization, respectively.

The runoff in period t is predicted as a function of precipitation and temperature in period t and t-1 as shown in (2):

$$Q_t = f(P_t, T_t, P_{t-1}, T_{t-1}) \quad (2)$$

where Q_t= runoff in time t; P_t = precipitation in time t; T_t= temperature in time t; P_{t-1} = precipitation in time t-1; T_{t-1}= temperature in time t-1; f= function between inputs and output.

Then, by using described inputs and runoff which produced by IHACRESS as the target, ANN is trained. 75% of the data are used for training step. The rest of the data are used in order to test. The correlation coefficient (R^2) and Root Mean Square Error (*RMSE*) are used as performance criteria.

IV. Case study

Aydoghmoush basin is located in north-east of Iran which covers an area of approximately 1'802 km^2 and its height is variable between 1'100 to 2'500 m. Average annual precipitation is 336.2 mm. The maximum and minimum temperature is 31.9 and -16.8˚C respectively. The data of 9 stations are used to determine the hydrologic parameters in the basin. The case study area and its 9 stations are shown in the Fig. 4:

Figure 4. the area of case study

V. Results and discussion

The result of test step is shown in Fig. 5:

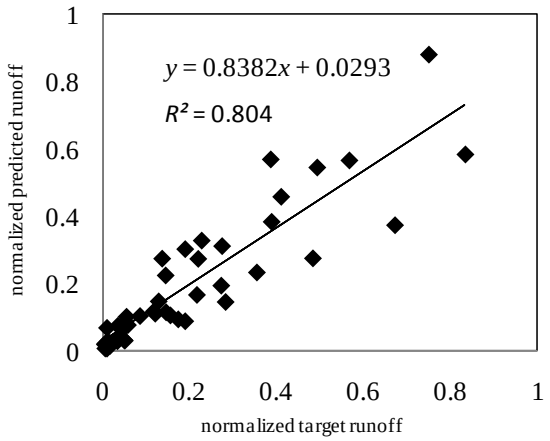

Figure 5. diagram of runoff prediction by ANN

In Fig. 5, the vertical coordinate shows normalized predicted runoff by ANN for the months that used in test step in the period of 2026-2039 and the horizontal coordinate shows the normalized target runoff for the same months which calculated by IHACRESS model.

The detailed information about performance of ANN in both train and test steps are shown in Table 1:

Table 1. detailed information of ANN's performance

train		test	
R^2	*RMSE*	R^2	*RMSE*
0.8907	0.0759	0.8040	0.0935

Finally estimated normalized runoff which is gained in both training and testing steps are changed to monthly runoff for period 2026-2039 by denormalization.

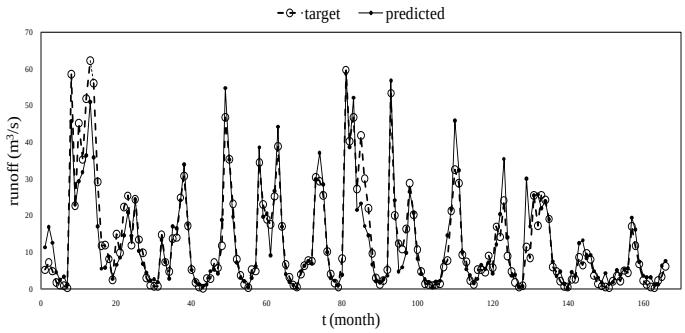

Figure 6. monthly runoff predicted under climate change in period 2026-2039

Considering of results of ANN in testing step, it is seemed that ANN tool with R^2=0.80 and *RMSE* =0.09, could be a efficient tool to predict the runoff under climate change. As is shown in Fig. 6, ANN can predict the peak flows with good accuracy. So ANN is suggested as an efficient and accurate data mining tool to investigate the climate change impacts on runoff.

VI. Conclusion

In this paper, one of the most important aspects of climate change impacts is investigated. Climate change impacts on the future runoff is essential to plan water resources. To this purpose, precipitation and temperature under climate change are estimated. Then, the produced runoff by using a data mining tool. In general, data mining models are tools for recognition of complex mathematical relationships between input and output parameters which are widely used in various fields. In the present paper, ANN as a data mining tool is used to predict runoff under climate change. To consider of the results, ANN could be a helpful model to this aim with R^2=0.80. So ANN is recommended to use for runoff prediction in future periods as a high performance method.

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