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Modeling of monthly rainfall and runoff of Urmia lake basin using "feed-forward neural network" and "time series analysis" model

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ABSTRACT

Urmia lake basin located in northwestern Iran is the second largest saline lake in the world. Due to many reasons i.e. climate changes, several dam constructions, building a bridge across the Lake, extra agricultural consumption and improper management of water resources, the water level of the lake has been decreased since 1997 and thousand hectares of emerged salty land has made numerous ecological and environmental problems. Therefore, an accurate forecast of the entrance runoff to the lake is important in managing the river flow and water transfer within basins. There are various methods for time-series based forecasting; in the presented study Feed-forward Neural Network and Autocorrelation Regressive Integrated Moving Average (ARIMA) models were applied to forecast the monthly rainfall in Urmia lake basin. The results showed that the estimated values of monthly rainfall through Feed-forward NN were close to ARIMA model with coefficient of correlation 0.62 and the root mean square error of 12.43 mm over the 6 years test period; then rainfall amount were predicted for a 6-year period starting from 2012 (2012–2017). Using the runoff coefficient regime which was calculated from

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parallel data of rainfall over the basin and resulted runoff for the period of 39 years, the future runoff were obtained through predicted rainfall over that period.

1. Introduction

Urmia lake with its previous lake area of approximately 5000–6000 km^2, had a crucial socio-economic and ecological role in the Northwestern part of Iran. But during the past 15 years water level has been decreased up to 5 m. Changes occurred in lake inflows due to the climate changes, overutilization of water resources, dam constructions and reduction of precipitation over the lake basin are the main factors which reduce the lake water level [13]. The most important factor in disruption of system inflow and outflow balance is the river discharge into the lake. A great percentage of inflows to the lake are through the rivers in comparison with rainfall over the lake and groundwater. Some detailed studies are required to understand the amount of rainfall over the lake basin in the coming years for the purpose of inflow estimating through rivers to the Lake.

Several techniques which have been used for rainfall forecasting since past century were basically linear, conceptual and statistical models. One of these popular and frequently used models was ARIMA model [16,23,17,28]. Weesakul and Lowanichchai [30] used ARIMA model for annual rainfall forecasting at 31 rainfall stations in Thailand. Mahsin et al. [20] used seasonal ARIMA model for monthly rainfall forecasting in Dhaka Division of Bangladesh.

In recent two decades, Artificial Neural Networks have become a valuable method for nonlinear phenomenon modeling i.e. rainfall–runoff modeling [1,26,6,8], reservoir inflow forecasting [22], stream flow prediction [5,7,19,25,18], sea level prediction [15], water level fluctuations [4,29] and rainfall prediction [27,3,11,2,10,9,21]. Based on these research outcomes ANNs could be appropriate method to simulate and forecasting.

Hung et al. [14] compared feed-forward neural network model with a simple persistent model for 75 rain gauge stations' hourly data in Bangkok, Thailand. They concluded that a generalized Feed-forward NN model using hyperbolic tangent transfer function achieved the best rainfall generalization with lead times varying from 1 to 3 h ahead. Moustris et al. [24] compared ANN with classical statistical methods at four meteorological stations in Greece in order to forecast the monthly mean and cumulative precipitation totals within a period of the next four consecutive months. They concluded that the ability of neural networks as a precipitation predictive tool seemed to be quite satisfactory. In the present work the Feed-forward NN and ARIMA models were applied for rainfall forecasting in Urmia lake basin and flow coefficient regime was used to estimate the entrance surface runoff to the lake.

2. Materials and methods

2.1. Study area description and problems

Urmia lake basin is located in northwest of Iran limited in 44° 07′E to 47° 53′E longitude and 35° 40′N to 38° 30′N latitude with total area of about 52,679 km^2 (Fig. 1). Urmia lake is the largest lake in Iran and one of the world's salt-saturated lakes that has significant role in moderating the climate of a vast area containing East and west Azarbaijan and Kurdistan provinces.

According to 39-year period of daily precipitation data (1973 to 2011) the annual mean precipitation over the basin is 352 mm. The annually increasing domestic, industrial and agricultural consumes as well as groundwater feeding along the river which were supplied through the river flow