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Application of Chaos Theory and Artificial Neural Networks to Evaluate Evaporation from Lake's Water Surface

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Introduction: Dynamic nature of hydrological phenomena and the limited availability of appropriate mathematical tools caused the most previous studies in this field led to the random and the probabilistic approach. So selection the best model for evaluation of these phenomena is essential and complex. Nowadays different models are used for evaluation and prediction of hydrological phenomena. Damle and Yalcin (2007) estimated river runoff by chaos theory. khatibi et al (2012) used artificial neural network and gene expression programming to predict relative humidity. Zounemat and Kisi (2015) evaluated chaotic behavior of marine wind-wave system of Caspian sea. One of the important hydrological phenomena is evaporation, especially in lakes. The investigation of deterministic and stochastic behavior of water evaporation values in the lakes in order to select the best simulation approach and capable of prediction is an important and controversial issue that has been studied in this research.

Materials and Methods: In the present paper, monthly values of evaporation are evaluated by two different models. Chaos theory and artificial neural network are used for the analysis of stochastic behavior and capability of prediction of water evaporation values in the Urmia Lake in northwestern of Iran. In recent years, Urmia Lake has unpleasant changes and drop in water level due to inappropriate management and climate change. One of the important factors related to climate change, is evaporation. Urmia Lake is a salt lake, and because of existence valuable ecology, environmental issues and maintenance of ecosystems of this lake are very important. So evaporation can have an essential role in the salinity, environmental and the hydrological cycle of the lake.

In this regard, according to the ability of chaos theory and artificial neural network to analysis nonlinear dynamic systems; monthly values of evaporation, during a 40-year period, are investigated and then predicted. So that, 10 years of data are applied to model validation and a four-year time horizon is predicted by each model. In the present paper, a multi-layer perceptron network with a hidden layer are used. Number of neurons in the hidden layer is determined by try and error. Also different input combinations are used to find out the best artificial neural network model. Prediction accuracy of models is evaluated by three indexes. These three indexes are mean absolute error (MAE), root mean squared error (RMSE) and determination coefficient (R^2).

Results and Discussion: Results of chaotic parameters such as a positive lyapunov exponent and the correlation dimension non-integer slope indicate that evaporation values in the Urmia Lake have chaotic behavior. So these values have not stochastic behavior and can be predicted by suitable models. Chaos theory and artificial neural network are used for prediction in this paper. Values of MAE, RMSE and R2 for validation data are 10.96, 14.67 and 0.97 for artificial neural network and 13.47, 16.92 and 0.97 for chaos theory, respectively. The determination coefficient is the same in the two models while the values of MAE and RMSE is lower in the artificial neural network. So error indexes indicate that the artificial neural network is slightly better than the chaos theory. In order to prediction by artificial neural network, The best input combination includes four time delays that they are values of a month ago, two months ago, eleven and twelve months ago. Because in the chaos theory only the evaporation time series is applied, in order to better comparison of artificial neural network and chaos theory, in the artificial neural network model only the evaporation time series is used. Results of the four-year time horizon indicate somewhat similar behavior of two models especially in the minimum and maximum values of time series. In the maximum and minimum value chaos theory and artificial neural network predict similar values while in the other values there are some difference and the artificial neural network model predicted values less than chaos theory.

Conclusions: The results obtained from the chaotic nature determination parameters of the evaporation data,

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positive lyapunov exponent and the correlation dimension non-integer slope; indicate the chaotic behavior of study time series. Therefore, the system has a hidden pattern (i.e., the system isn't Stochastic). The verification results indicate the high accuracy of chaos theory and neural network models - a little more accurate - and it was found that both models have similar accuracy in prediction of the future evaporation values or data that haven't been recorded in the past.

Keywords: Hydrological phenomena, Lyapunov exponent, Prediction, Urmia lake