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Sensitivity analysis of the artificial neural network outputs in simulation of the evaporation process at different climatologic regimes

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ABSTRACT

This study follows three aims; firstly to develop and examine three different Artificial Neural Networks (ANNs) viz.: Multi-Layer Perceptron (MLP), Radial Basis Neural Network (RBNN) and Elman network for estimating daily evaporation rate of Tabriz and Urmia cities using measured hydro-meteorological data; second to compare the results of ANN models with three physically-based models include, Energy balance, Aerodynamic, and Penman models and also black-box Multiple Linear Regression (MLR) model; and finally to perform a sensitivity analysis to investigate the effect of each input parameter on the output in terms of magnitude and direction. The used meteorological data set to develop the models for estimation of daily evaporation includes daily air temperature, evaporation, solar radiation, air pressure, relative humidity, and wind speed measured at synoptic stations of Tabriz and Urmia cities which have almost distinct climatologic conditions. The obtained results denote to the superiority of the ANN models on the classic models. Also based on the comparisons, the MLP network performs better than the RBNN and Elman network so that in the next step, sensitivity analysis is performed by the Partial Derivation (PaD) and Weights methods on the MLP outputs. Sensitivity analysis results show although air temperature, solar radiation and the amount of evaporation at previous time step are the effective parameters in estimation of daily evaporation at both regions, due to the climatologic condition wind speed and relative humidity are other predominant parameters in Tabriz and Urmia, respectively.

1. Introduction

Evaporation as a major meteorological component of the hydrologic cycle plays a key role in climate change and water resources studies in arid and semi-arid climatic regions. Although there are empirical methods available for estimating evaporation, their performances are not satisfactory because evaporation is an incidental, non-linear, complex and unsteady process, so it is difficult to derive an accurate physical-based formula to represent all the physical meaning involved. As a result, there is a new trend in using data mining techniques such as Artificial Neural Network (ANN) to estimate evaporation. Chauhan and Shrivastava [1] used ANN approach to identify the best model in estimating evapotranspiration against climatic based methods for the Mahanadi reservoir area located in India, Moghaddamnia et al. [2] utilized ANN and adaptive neuro-fuzzy inference system (ANFIS) techniques to estimate evaporation in semi-arid regions and to tackle the problem of the best input data combination and how many data points should be used in the model calibration via the Gamma test. Deswal and Pal [3] used ANN method to study the influence of different combinations of meteorological parameters on evaporation losses from reservoirs. Jain et al. [4] investigated ANN accuracy in predicting evaporation with limited climatic data and used a procedure to evaluate the effects of input variables on the output variable using the weight connections of ANN models. Rahimikhoob [5] compared ANN technique with some empirical methods of evaporation estimation in Khuzestan plain in the southwest of Iran. Tan et al. [6] evaluated the applicability of the radiation-based, mass transfer, temperature-based and ANN models in estimating hourly and daily evaporation rates for an area with an equatorial climate. Among the empirical models, only the radiation-based model was found to be applicable for modeling the hourly and daily evaporations. ANN models are generally more accurate than the empirical models if appropriate network architecture is selected and a sufficient number of data points are used for training the network. Shirsath and Singh [7] utilized ANN, Multiple Linear Regression (MLR) and climate based (e.g., Penman, Priestley–Taylor and Stephens and Stewart) models for estimation of daily pan evaporation; results

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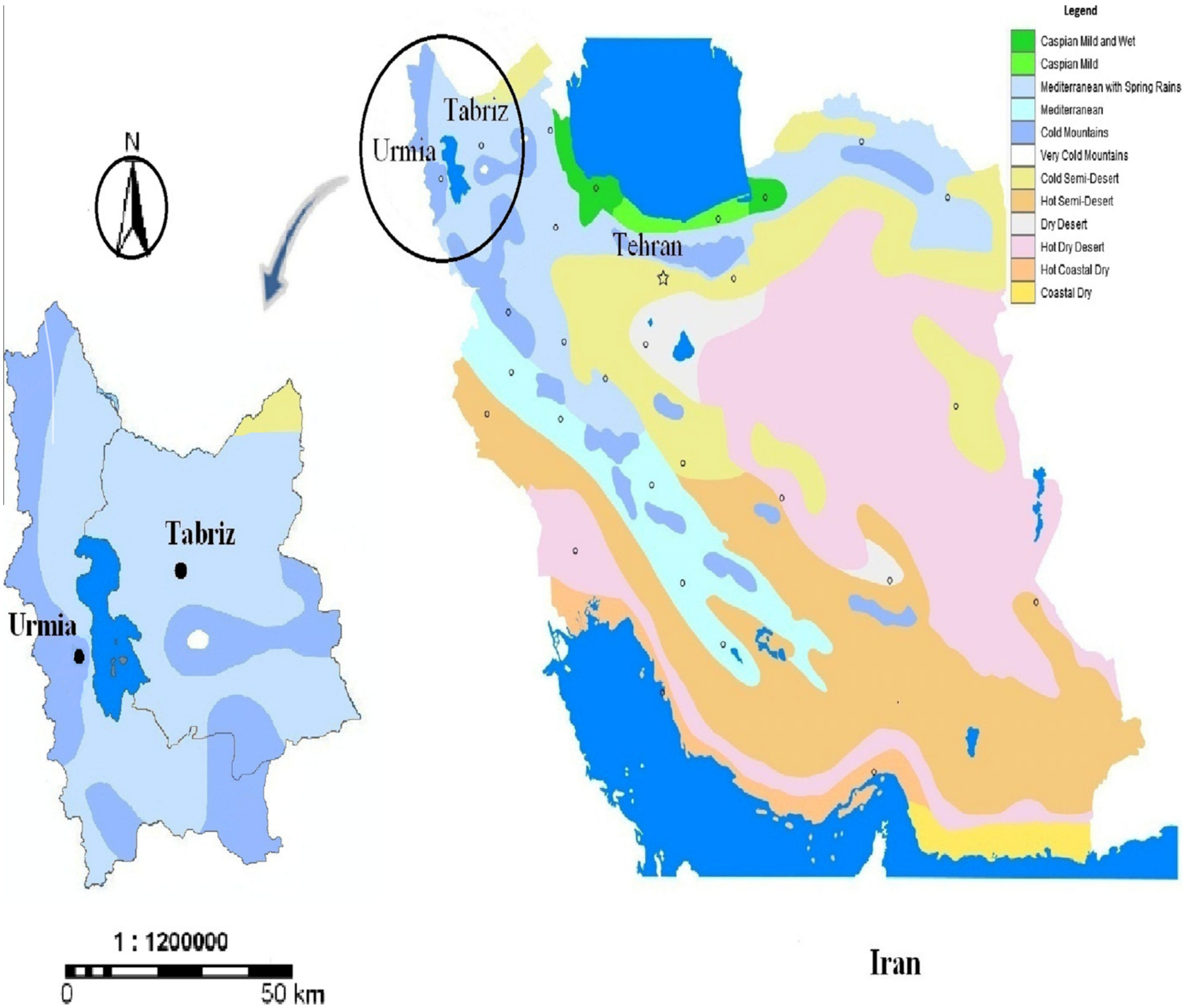

Fig. 1. Study areas location map.

showed that there is slightly better agreement between the ANN estimations and measurements of daily pan evaporation than other models. Kisi [8] investigated the abilities of three different ANN techniques i.e., Multi-Layer Perceptron (MLP), Radial Basis Neural Network (RBNN) and Generalized Regression Neural Network (GRNN) to estimate pan evaporation rate and the results showed that the MLP and RBNN techniques could be successfully employed to model the evaporation process using the available climatic data.

As well as evaporation, the study of ANN has recently aroused great interest at different fields of hydro-meteorology. As a few examples of many such studies, a GRNN was used for river suspended sediment estimation by Cigizoglu and Alp [9]; Nourani et al. [10,11] investigated the wavelet analysis linked to the ANN concept for hydrologic simulations of the Ligvanchai watershed. Nourani [12] utilized the ANN technique for modeling suspended sediment load of a delta mouth. In order to perform spatiotemporal

Table 1
Statistics analysis of training and testing data sets.

Variable	Tabriz								Urmia							
	Training set				Testing set				Training set				Testing set			
	Mean	Max	Min	Std.	Mean	Max	Min	Std.	Mean	Max	Min	Std.	Mean	Max	Min	Std.
E_t (mm/d)	5.93	22.1	0.10	5.12	5.85	21.2	0.10	5.19	4.193	13.6	0.011	3.234	4.335	13.2	0.016	3.561
T (°C)	13.21	33.17	−14.97	10.06	13.12	34.02	−12.17	11.07	11.95	28.75	−12.95	9.529	10.88	26.97	−8.875	9.124
R_H (%)	50.25	96.12	9.90	17.54	50.34	96.25	14.37	17.14	57.52	100	15.62	15.45	59.31	98.12	28.75	15.62
U_2 (m/s)	3.28	9.37	0.25	1.54	3.55	9.62	0.50	1.49	2.176	8.25	0.1	1.100	1.614	7.375	0.1	1.212
R_a (w/m^2)	386.3	894.0	20.40	194.7	354.6	791.0	24.84	178.4	443.9	950.2	11.07	184.6	401.0	943.1	38	231.9
P (Hpa)	864.2	878.2	848.3	4.32	864.4	879.7	851.8	4.41	867.3	881.1	851.3	4.483	868.0	881.4	854.9	4.451