Application of Soft Computing Model for Hydrologic Forecasting

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ABSTRACT

Accurate forecasting of pan evaporation (PE) is very important for monitoring, survey, and management of water resources. The purpose of this study is to develop and apply Kohonen self-organizing feature maps neural networks model (KSOFM-NNM) to forecast the daily PE for the dry climate region in south western Iran. KSOFM-NNM for Ahwaz station was used to forecast daily PE on the basis of temperature-based, radiation-based, and sunshine duration-based input combinations. The measurements at Ahwaz station in south western Iran, for the period of January 2002 – December 2008, were used for training, cross-validation and testing data of KSOFM-NNM. The results obtained by TEM 1 produced the best results among other combinations for Ahwaz station. Based on the comparisons, it was found that KSOFM-NNM can be employed successfully for forecasting the daily PE from the limited climatic data in south western Iran.

Key words : forecasting, Kohonen self-organizing feature maps, pan evaporation, Iran

1. INTRODUCTION

KSOFM-NNM transforms the input of arbitrary dimension into a one or two dimensional discrete map subject to a topological (neighborhood preserving) constraint. The feature maps are computed using Kohonen unsupervised learning. The output of the SOFM can be used as input to a supervised classification neural network such as the MLP. This network's key advantage is the clustering produced by the SOFM which reduces the input space into representative features using a self-organizing process. Hence the underlying structure of the input space is kept, while the dimensionality of the space is reduced. Chang et al. (2010) proposed a self-organizing map (SOM) neural network to assess the variability of daily evaporation based on meteorological variables. They demonstrated that the topological structures of SOM could give a meaningful map to present the clusters of meteorological variables and the networks could well estimate the daily evaporation.

The present study investigates the forecasting abilities of KSOFM-NNM to forecast the daily PE. The subsequent parts of this paper are organized as follows: the second section deals with describing the used data as well as KSOFM-NNM. The third part presents the applied statistical measures for model analysis, followed by the fourth section including results and discussions. Finally, the last section provides the conclusions of the present study.

2. MATERIAL AND METHODS

2.1. USED DATA

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The daily climatic data of two automated weather stations, Ahwaz station (latitude 31°20'N, longitude 48°40'E, height 22.5m above mean sea level) and Izeh station (latitude 31°51'N, longitude 49°52'E, height 767 m above mean sea level), operated by the Khozestan Meteorological Organization (KMO) in Iran, were used in this study. The data of Ahwaz and Izeh stations consisted of seven years (2002-2008) of daily records of mean air temperature (T), mean wind speed (U), sunshine duration (SD), mean relative humidity (RH), extraterrestrial radiation (R), and pan evaporation (PE). The first five years data (2002-2006) were used to train KSOFM-NNM. And, the remaining two years data (2007-2008) were used to cross-validate (2007) and test (2008) KSOFM-NNM. Table 1 shows the statistical parameters of the used data during the study period. In the Table 1, the X_{max}, X_{min}, X_{mean}, S_x, C_v, and C_{sx} denote the maximum, minimum, mean, standard deviation, coefficient of variation, and skewness coefficient, respectively. It can be seen from the Table 1 that the distribution of the training, cross validation, and testing data is similar to each other (see the C_{sx} values).

2.2. THE KOHONEN SELF-ORGANIZING FEATURE MAPS NEURAL NETWORKS MODEL

Kohonen self-organizing feature maps neural networks model (KSOFM-NNM) performs mapping from a continuous input space to a discrete output space, preserving the topological properties of the input nodes (Kohonen 1990, 2001; Tsoukalas and Uhrig 1997; Principe et al. 2000; Hsu et al. 2002; Lin and Chen 2005, 2006; Chang et al. 2007; Lin and Wu 2007, 2009). KSOFM-NNM consists of four layers, that is, the input layer, the Kohonen layer, the hidden layer, and the output layer. The input layer is composed of *n* input nodes, each connected to all nodes of the Kohonen layer. The Kohonen layer consists of [n_1 X n_1] matrixes. In this study, KSOFM-NNM classifies each input node and determines to which node in the hidden layer it must be routed for forecasting of the daily PE of the output layer. Fig. 1 shows the developed structure of KSOFM-NNM based on TEM 3 (8-[5 X 5]-20-1) in this study.

3. RESULTS AND DISCUSSION

3.1 THE PERFORMANCE OF KSOFM-NNM

The general structure of KSOFM-NNM includes the input layer, Kohonen layer, hidden layer, and output layer. Determining the appropriate size of matrixes in the Kohonen layer is important for the model efficiency. Since there is no standard method for finding the optimal number of matrixes in the Kohonen layer, the optimal matrixes size in the Kohonen layer is based on trial and error method in the circumstance. In this study, the Kohonen layer consists of [5 X 5] matrixes with the minimum RMSE of all the input combinations using trial and error method among the various matrixes including [4 X 4, 5 X 5, 6 X 6, and 7 X 7]. Chang et al. (2010) determined the optimal size SOM networks with [6 X 6] matrixes using trial and error method among the various matrixes such as [3 X 3, 4 X 4, 5 X 5, 6 X 6, 7 X 7, and 8 X 8]. Fig. 2(a)-(f) shows the comparison of the observed and forecasted PE of optimal KSOFM-NNM during the testing performance for Ahwaz and Izeh stations, respectively. The better accuracy of TEM 1 can be clearly seen from the Fig. 2(a)-(f) for the both stations.

4. CONCLUSIONS

In this study, the accuracy of soft computing technique, Kohonen self-organizing feature maps neural networks model (KSOFM-NNM) was investigated for forecasting the daily PE. The observed PE from the

Ahwaz and Izeh stations in Iran were used for training, cross-validation, and testing of KSOFM-NNM. KSOFM-NNM implemented to forecast the daily PE using the temperature-based, radiation-based, and sunshine duration-based input combinations. This implementation produced high quality of forecasting for the all input combinations. The results presented here showed the capability of the soft computing model for forecasting the nonlinear behavior such as the daily PE in terms of CC, RMSE, SI, and NS. TEM 1 whose inputs are T_{t-1}, U_t, RH_t, PE_{t-1} produced the best results among other input combinations for Ahwaz and Izeh stations, respectively. Forecasting accuracy of the soft computing model was found to be decreased by increasing the lag-time intervals.

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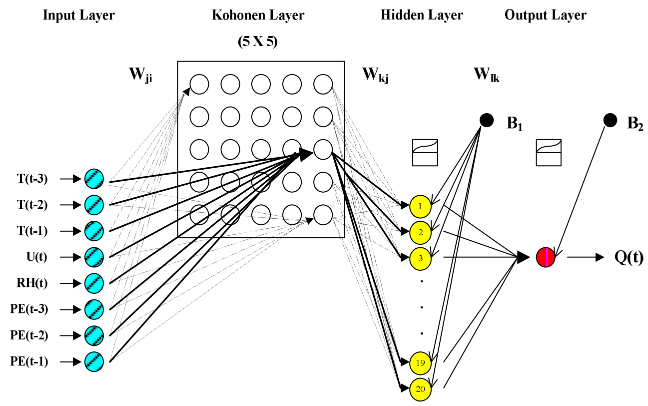
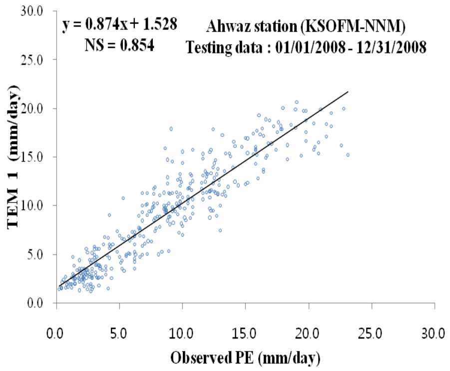


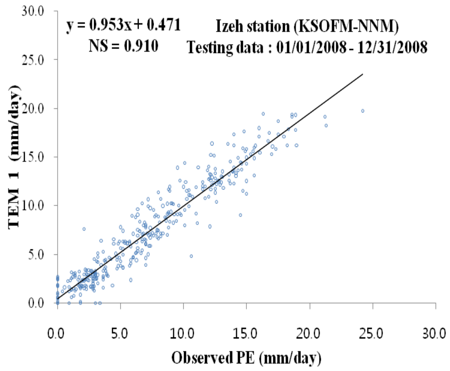
Fig. 1 Developed structure of KSOFM-NNM based on TEM 3 (8-[5 X 5]-20-1)

Table 1 Statistical parameters of applied PE data during the study period

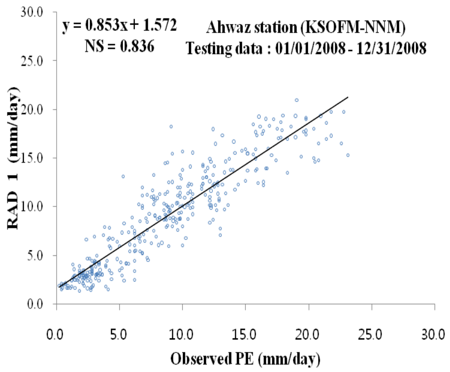
Station	Study period	Patterns	Statistical parameters of recorded data					
			X_{max}	X_{min}	X_{mean}	S_x	C_v	C_{sx}
Ahwaz	Training	1825	26.00	0.00	9.04	5.86	0.65	0.44
	Cross-validation	365	22.80	0.40	8.22	5.16	0.63	0.54
	Testing	365	23.10	0.20	8.73	5.56	0.64	0.49
Izeh	Training	1825	26.40	0.01	7.23	5.06	0.70	0.55
	Cross-validation	365	22.50	0.01	6.82	4.78	0.70	0.62
	Testing	365	24.20	0.01	7.41	5.09	0.69	0.56



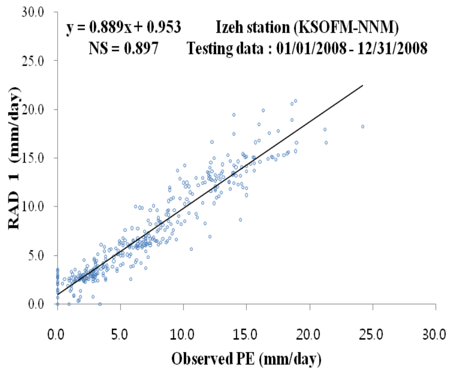
(a) TEM 1 (Ahwaz station)



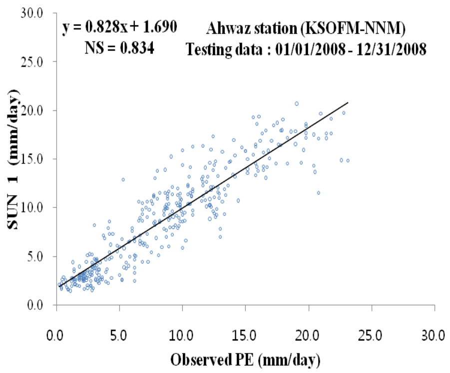
(b) TEM 1 (Izeh station)



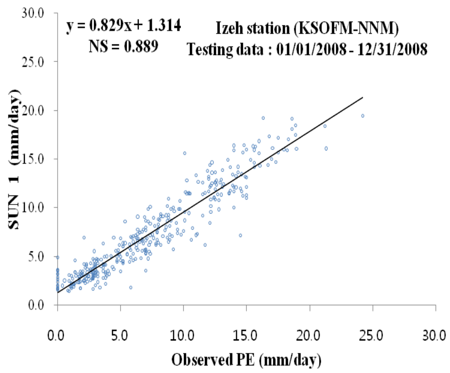
(c) RAD 1 (Ahwaz station)



(d) RAD 1 (Izeh station)



(e) SUN 1 (Ahwaz station)



(f) SUN 1 (Izeh station)

Fig. 2 Comparison of the observed and forecasted PE of optimal KSOFM-NNM (Testing data)