Comparison of SVM, ANFIS and GEP in modeling monthly potential evapotranspiration in an arid region (Case study: Sistan and Baluchestan Province, Iran)

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ABSTRACT

Evapotranspiration is an important component in planning and management of water resources. It depends on climatic factors and the influence of these factors on each other makes evapotranspiration estimation difficult. This study attempts to explore the possibility of predicting this important component using three different heuristic methods: support vector machine (SVM), adaptive neuro-fuzzy inference system (ANFIS) and gene expression programming (GEP). In this regard, according to the Food and Agriculture Organization of the United Nations (FAO) Penman-Monteith equation, the monthly potential evapotranspiration in four synoptic stations (Zahedan, Zabol, Iranshahr, and Chabahar) was calculated using monthly weather data. The weather data were then used as inputs to the SVM, ANFIS and GEP models to estimate potential evapotranspiration. Five different input combinations were tried in the applications. The results of SVM, ANFIS and GEP models were compared based on the coefficient of determination ($R^2$), mean absolute error and root mean square error. Findings showed that the SVM model, whose inputs are average air temperature, relative humidity, wind speed, and sunny hours of the current and one previous month, performed better than the other models for the Zahedan, Zabol, Iranshahr, and Chabahar stations. Comparison of the three heuristic methods indicated that in all stations, the SVM, GEP and ANFIS models took first, second, and third place in estimation of the monthly potential evapotranspiration, respectively.

Key words | adaptive neuro-fuzzy inference system, arid region, climate parameters, gene expression programming, modeling, support vector machine

INTRODUCTION

As one of the main components of water balance in a region, evapotranspiration is among the important factors which should be considered for irrigation planning.

Accurate estimation of crop water demand has a positive effect on reducing water crisis, especially in arid and semi-arid areas. There are numerous methods for calculating evapotranspiration which can be generally categorized into direct and indirect methods. One of the most common indirect methods is to use the estimated values of evapotranspiration in a desired plant using a modified FAO Penman-Monteith equation (Goyal 2004).

In this method, after determining the water requirement in the reference crop, the value is computed on the basis of the crop coefficients (Allen et al. 1998). Despite the permissible precision level of the Penman-Monteith method, but considering the large number of input data required, researchers have made a lot of effort to simplify the indirect methods in order to obtain precise estimation of evapotranspiration.

Recently, heuristic methods have been successfully used in solving water resources problems (Kisi 2007; Guven & Gunal 2008; Mohammadrezapour et al. 2012, 2017;
Najafzadeh & Barani 2013; Najafzadeh et al. 2016a, 2016b, 2017a, 2017b, 2017c; Zahiri & Najafzadeh 2017). The meta-heuristic methods such as the adaptive neuro-fuzzy inference system (ANFIS), support vector machine (SVM), and gene expression programming (GEP) have a high potential for estimating the amount of evaporation-transpiration. The main advantages of these models are: (i) they do not require mathematical relationships for such complex phenomena; (ii) these models are added to the optimization models; their inputs are ready for sensitivity analysis and their optimal structure is automatically extracted. For these reasons, many studies have focused on evaluating artificial intelligence models in predicting potential evapotranspiration. Guo et al. (2011) estimated evapotranspiration in a reference plant on a daily basis by using SVM. From their study the SVM had the ability to estimate the evapotranspiration in the reference plant up to 90% with the values calculated using the Penman-Monteith method (Gou et al. 2011). In the study of Aytac & Seydou (2012) potential evapotranspiration was predicted by GEP using a ten-year climatic data in the landlocked coastal country, Burkina Faso. The results showed that the GEP had a permissible performance to provide a numerical model based on regional data. Furthermore Shiri et al. (2012) employed a GEP model for estimating reference evapotranspiration in four weather stations, located in the Basque country, in northern Spain.

They selected the Penman-Monteith method as the reference to compare the GEP results with those obtained using ANFIS, Priestly-Taylor, and Hargreaves-Samani models. The results showed that the GEP model was better than the ANFIS, Priestly-Taylor, and Hargreaves and Samani models; the ANFIS model was the next best. In two parts of Northern California, SVR, neural networks, and experimental models were used to estimate daily evapotranspiration in a reference plant (Guo et al. 2011; Kisi & Zounemat-Kermani 2014). The results showed that in both parts of California, the SVM model had higher accuracy than other models. Moreover, Terzi (2013) compared the result of GEP with ANFIS to estimate daily evaporation of a lake located in southwest Turkey using various input combinations and concluded that the GEP model had better results than the ANFIS.

The results of Gulay & Buyukyildiz (2014) demonstrated that the SVM and fuzzy logic models had sufficient accuracy to estimate daily evaporation in comparison with empirical equations. Also, Wen et al. (2015) indicated that SVM model produced more accurate estimation of daily reference evapotranspiration (ET0) using limited climatic data than those obtained using ANN model.

Considering the importance of accurate and timely determination of potential evapotranspiration in water balance calculations, simulation of plant produce, irrigation programming on the one hand and lack of appropriate meteorological data on the other hand, providing an efficient model for introducing this parameter is quite essential. Hence, the aim of this study is to evaluate the accuracy of neuro-fuzzy models, GEP, and SVM in estimation of potential evapotranspiration of an arid region on a monthly basis. Ultimately, results of proposed intelligent models are appraised qualitatively and quantitatively in terms of various statistical parameters.

**MATERIALS AND METHODS**

**Study area**

The study was conducted in the Sistan and Baluchistan Province, which lies between 25° 3’ N to 31° 9’ N (latitude) and 58° 49’ E to 63° 20’ E (longitude) in southeastern Iran, covering an area of approximately 181,785 km² (Figure 1). The data used in this study were gathered from Zabol, Zahedan, Iranshahr, and Chabahar stations. In each of these stations, the long-term statistics of climate parameters including air temperature, relative humidity, sunny hours, and wind speed were collected from the Regional Water Company of Sistan and Balochestan on a monthly basis during the period of 1970–2010. Table 1 shows the mean of the variables used for modeling monthly evapotranspiration during the statistical period for each station.

**FAO Penman-Monteith**

Before using artificial intelligence models, the evapotranspiration rate during the selected statistical period in all the stations was first calculated on a monthly basis using the following modified FAO-56 Penman-Monteith
relationship (Allen et al. 1998):

\[ ET_0 = \frac{0.408 \Delta (R_n - G) + \gamma (900/T + 273) u_2 (e_s - e_a)}{\Delta + \gamma (1 + 0.34u_2)} \tag{1} \]

where \( ET_0 \) is the reference evapotranspiration rate (mm·day\(^{-1}\)), \( R_n \) is the net radiation at plant level (MJ·m\(^{-2}\)·day\(^{-1}\)), \( G \) is the soil heat flow density (MJ·m\(^{-2}\)·day\(^{-1}\)), \( \gamma \): psychrometric constant coefficient (KPa/°C), \( T \) is the average air temperature (°C), \( u_2 \): speed at 2 m height (ms\(^{-1}\)), \( e_s - e_a \) is the saturation vapor pressure deficit (Kpa), and \( \Delta \) is the vapor pressure curve slope (KPa/°C). Then, these values were inserted as inputs to the selected intelligent models (ANFIS, GEP and SVM) for predicting monthly reference evapotranspiration. To perform all the proposed predictive approaches, two-thirds of the input data were used in the training phase and the remaining one-third was used in the testing phase.

Another model used in this study is ANFIS. Jang (1993) introduced the ANFIS model which has the ability to combine the abilities of fuzzy logic and artificial neural network methods (Shirsath & Singh, 2010; Remesan et al. 2008). In the neuro-fuzzy model, the training process consists of two stages. In the first phase, the premise parameters (membership functions) are assumed constant, so using the least squares method, the parameters of the consequent part (rule equations’ coefficients) are identified. Then, in the second phase, the error signals are post-propagated. Through the ANFIS model, rules are fixed and the shape of membership functions is optimized. Obtaining an accuracy level for the ANFIS model is at the mercy of a range of variables, type of membership functions, fuzzy rules, and the number of membership functions.

### Table 1 | Statistical mean of parameters used in modeling potential evapotranspiration

<table>
<thead>
<tr>
<th>Station</th>
<th>Longitude</th>
<th>Latitude</th>
<th>Sunny hours (hr)</th>
<th>Wind speed (km/hr)</th>
<th>Relative humidity (%)</th>
<th>Mean temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zahedan</td>
<td>29–28</td>
<td>60–53</td>
<td>9.1</td>
<td>276.9</td>
<td>33.1</td>
<td>18.6</td>
</tr>
<tr>
<td>Zabol</td>
<td>31–13</td>
<td>61–29</td>
<td>8.8</td>
<td>457.8</td>
<td>37.4</td>
<td>22.2</td>
</tr>
<tr>
<td>Iranshahr</td>
<td>27–12</td>
<td>60–42</td>
<td>9.2</td>
<td>180.2</td>
<td>30.3</td>
<td>26.8</td>
</tr>
<tr>
<td>Chabahar</td>
<td>25–14</td>
<td>60–30</td>
<td>8.6</td>
<td>259</td>
<td>72.7</td>
<td>26.3</td>
</tr>
</tbody>
</table>
It can be calibrated without expert knowledge. Furthermore fuzzy membership functions can be easily adjusted by using different optimization algorithms. The ANFIS model has a capacity for fast learning and adaptation. Details of the ANFIS method can be obtained in literature (Jang 1993).

**GEP model**

Gene-expression programming is a self-centered programming method (Koza 1992). In this method, first, a target function is identified for the problem. Then, using a step-by-step process and by changing function structure, the target function is obtained with minimal error. The fundamental difference between GEP and genetic algorithms (GA) is the unique nature of each individual so that the individuals in the genetic algorithm are the linear rows with a fixed length (chromosomes). In GEP, however, the individuals include distinct branches of mathematical symbols. In this study, a combination of all operators, such as jump, back, three different types of transposition and three types of recombination operators were used. The advantage of the GEP is that it has explicit formulation. This give some insight into the nature of the investigated phenomenon. It can be easily used in practical applications. Details of this method can be found in Koza (1992).

**Support vector machine model**

The SVM model is a relatively new technique which has recently proven to have a better performance in categorization and regression of multi-layer perceptron neural networks than the older methods. One of its advantages is that it works with fewer training data and variables, but based on the training data, it is more sensitive to variations in variables. A learning machine (f) takes an input (x) and converts it into an output using α weights. Crucial variables in SVMs are: variable c which controls the margins and the size of remoteness variables; Gamma variable which in an SVM should be selected in an insensitive reducing function. Epsilon (ε) also affects the flexibility of the responses obtained from SVMs. It also affects the complexity and generalization ability of the network. The Kernel function is a weighting function which is used in non-parametric forecasting techniques (Mohandes et al. 2004). The main advantages of the SVM model is that it uses kernel functions to get expert knowledge about the investigated phenomenon so that the model complexity together with estimation error is simultaneously minimized.

**Input variables of models**

In this research, five combinations of input variables - average air temperature (T), sunny hours (S), wind speed (W), an relative humidity (R) - were considered; see Table 2.

The input variables required for the FAO-56 Penman-Monteith (PM) equation are also included in the table. As seen from the table, the PM needs more variables than the data driven approaches especially for the first three patterns.

The unit measurements of \( T, T_{\text{min}}, T_{\text{max}}, S, R, \) and \( W \) are \( ^\circ C \), (hours), (%) and (km/hour), respectively.

To model the potential evapotranspiration, an inference neuro-fuzzy system and SVM, MATLAB software were used. Moreover, GeneXproTools was used for implementing the GEP. Two-thirds of the data were used for training applied models and the remaining one-third was used for testing.

**Evaluation criteria**

The statistical measures include the coefficient of determination (\( R^2 \)) which expresses the coordination of data predicted by the models and the FAO Penman-Monteith \( E_{\text{T}} \), as well as the root mean square error (RMSE). Also mean absolute error (MAE) were used to check and evaluate the accuracy of the models. The mentioned criteria can

<table>
<thead>
<tr>
<th>Pattern</th>
<th>Input variable in patterns</th>
<th>Input variables required for FAO-56 Penman-Monteith equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TSR</td>
<td>( T_{\text{min}}, T_{\text{max}}, T, R_n, R, W )</td>
</tr>
<tr>
<td>2</td>
<td>TSW</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>TRW</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>TSRW</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>TSRW(TSRW)-1</td>
<td></td>
</tr>
</tbody>
</table>
be calculated using the following equations:

\[
R^2 = \left( \frac{\sum_{i=1}^{N} (ET_{O}^i - ET_{E}^i)(ET_{E}^i - ET_{O}^i)}{\sqrt{\sum_{i=1}^{N} (ET_{O}^i - ET_{O}^i)^2 \sum_{i=1}^{N} (ET_{E}^i - ET_{E}^i)^2}} \right)^2
\]

(2)

\[
RMSE = \sqrt{\frac{\sum_{i=1}^{N} (ET_{E}^i - ET_{O}^i)^2}{N}}
\]

(3)

\[
MAE = \frac{1}{M} \sum_{i=1}^{M} \left| \frac{ET_{E}^i - ET_{O}^i}{ET_{E}^i} \right|
\]

(4)

where \( ET_{O}^i \) and \( ET_{E}^i \) respectively are the observed and predicted values at the time step \( i \), and \( ET_{E} \) and \( ET_{O} \) are the means of the observed and predicted values. \( N \) represents the number of data.

RESULTS AND DISCUSSION

In this section, estimation of potential evapotranspiration using ANFIS, GEP, and SVM models are evaluated quantitatively with aid of Equations (2)–(4). Furthermore, in terms of qualitative comparisons, scatter plots of the predicted evapotranspiration versus observed ones are presented.

Results of ANFIS model

In neuro-fuzzy modeling, there are parameters whose variation makes changes in the model performance and affects the convergence speed as well as the quality of the predictions. In order to obtain the best combination of parameters, a trial and error method was used. The most important issue for the ANFIS modeling is the selection of membership function.

Five functions, namely triangular, trapezoidal, Gaussian, Gaussian 2, and bell-like, were tested in this study. After trial and error, the Gaussian function was considered the most efficient MF in terms of giving lower training error and additionally was used to develop the ANFIS model. The evaluation results of various input combinations for the proposed ANFIS models are shown in Table 3 for the test phase.

As shown in Table 3, pattern 2 in Zahedan station, pattern 3 in Zabol station, pattern 5 in Iranshahr station and pattern 3 in Chabahar station have the highest values of coefficient of determination, while patterns 4, 5, 3, and 5 have the lowest values in these stations, respectively.

Results of GEP model

The GEP model was performed for all the stations in GeneXproTools software. In GEP modeling, the best value for some parameters is obtained based on trial and error. In this case, the number of chromosomes \( (n = 30) \), the number of genes in each chromosome \( (n = 3) \), and the cumulative link function were selected. The evaluation results of various combinations of input in GEP models are presented in Table 4.

As seen in Table 4, pattern 4 has the lowest RMSE and the highest coefficient of determination in the Zahedan, Zabol, Iranshahr, and Chabahar stations, whereas patterns 5, 3, 1, and 2 respectively have the worst results in these stations. It should be noted that the GEP3 model whose inputs are average temperature, sunny hours and wind
speed also has good accuracy in modeling ET₀ in Iranshar, Zabol and Zahedan stations.

**SVM model results**

An SVM model was conducted for the Zabol, Zahedan, Iranshahr, and Chabahar stations using MATLAB software. In order to improve the performance of SVM, numerous trial and error operations were carried out to get the best values for c, gamma parameter and Kernel functions. The ideal values for parameter c were obtained in all stations, ranging from 0.65 to 1.25 and the gamma parameter values ranging from 5 to 10 were obtained. Moreover, the used Kernel functions include linear and radial basis functions.

As shown in Table 5, patterns 5, 3, 5 and 5 had the lowest RMSE and MAE and the highest coefficients of determination in the Zahedan, Zabol, Iranshahr, and Chabahar stations, respectively.

**Evaluating models at each station**

The overview and comparison of neuro-fuzzy, GEP and SVM models show that it is impossible to suggest a special pattern with suitable accuracy for all the stations to estimate monthly evapotranspiration, so a separate superior model pattern should be introduced for all stations. In Zahedan station, from the ANFIS results the model (ANFIS2) which has the highest coefficient of determination and the least RMSE, known as a superior pattern. Moreover, the results of the GEP model in this station show that pattern 4 (GEP4) provided the most accurate estimation of ET₀, with R² of 0.97, RMSE of 0.453 and MAE of 0.102.

The results of the SVM model indicate that pattern 5 (SVM5) has the best statistics for this station. Considering the results of three models in Zahedan station shows that the SVM model with the grouped variables of pattern 5 (SVM5) is selected as a superior model and GEP model with pattern 4 (GEP4) has stood at the second rank of accuracy level to estimate monthly potential evapotranspiration. The neuro-fuzzy model (ANFIS2) is ranked in the third place.

In Zabol station, the ANFIS 3 model whose inputs are average air temperature, relative humidity, and wind speed shows superior accuracy. Moreover, the results of the GEP model in this station show that pattern 4 (GEP4) has the highest level of accuracy. The results of the SVM model

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**Table 4** Test results of the GEP models (errors are based on mm/day)

<table>
<thead>
<tr>
<th>Model name</th>
<th>Chabahar</th>
<th></th>
<th>Iranshahr</th>
<th></th>
<th>Zabol</th>
<th></th>
<th>Zahedan</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>GEP</td>
<td>R² 0.775</td>
<td>RMSE 0.542</td>
<td>MAE 0.110</td>
<td>R² 0.952</td>
<td>RMSE 1.581</td>
<td>MAE 0.212</td>
<td>R² 0.954</td>
<td>RMSE 1.319</td>
</tr>
<tr>
<td>GEP2</td>
<td>R² 0.758</td>
<td>RMSE 0.595</td>
<td>MAE 0.114</td>
<td>R² 0.970</td>
<td>RMSE 0.637</td>
<td>MAE 0.065</td>
<td>R² 0.950</td>
<td>RMSE 1.531</td>
</tr>
<tr>
<td>GEP3</td>
<td>R² 0.732</td>
<td>RMSE 0.585</td>
<td>MAE 0.112</td>
<td>R² 0.974</td>
<td>RMSE 0.983</td>
<td>MAE 0.081</td>
<td>R² 0.913</td>
<td>RMSE 1.597</td>
</tr>
<tr>
<td>GEP4</td>
<td>R² 0.815</td>
<td>RMSE 0.495</td>
<td>MAE 0.105</td>
<td>R² 0.982</td>
<td>RMSE 0.421</td>
<td>MAE 0.058</td>
<td>R² 0.981</td>
<td>RMSE 1.060</td>
</tr>
<tr>
<td>GEP5</td>
<td>R² 0.802</td>
<td>RMSE 0.538</td>
<td>MAE 0.100</td>
<td>R² 0.985</td>
<td>RMSE 1.138</td>
<td>MAE 0.121</td>
<td>R² 0.946</td>
<td>RMSE 1.502</td>
</tr>
</tbody>
</table>

**Table 5** Test results of the SVM models (errors are based on mm/day)

<table>
<thead>
<tr>
<th>Model name</th>
<th>Chabahar</th>
<th></th>
<th>Iranshahr</th>
<th></th>
<th>Zabol</th>
<th></th>
<th>Zahedan</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>SVM</td>
<td>R² 0.777</td>
<td>RMSE 0.459</td>
<td>MAE 0.093</td>
<td>R² 0.905</td>
<td>RMSE 1.426</td>
<td>MAE 0.112</td>
<td>R² 0.970</td>
<td>RMSE 0.842</td>
</tr>
<tr>
<td>SVM2</td>
<td>R² 0.855</td>
<td>RMSE 0.382</td>
<td>MAE 0.076</td>
<td>R² 0.960</td>
<td>RMSE 0.718</td>
<td>MAE 0.069</td>
<td>R² 0.994</td>
<td>RMSE 0.645</td>
</tr>
<tr>
<td>SVM3</td>
<td>R² 0.821</td>
<td>RMSE 0.413</td>
<td>MAE 0.081</td>
<td>R² 0.987</td>
<td>RMSE 0.39</td>
<td>MAE 0.039</td>
<td>R² 0.997</td>
<td>RMSE 0.246</td>
</tr>
<tr>
<td>SVM4</td>
<td>R² 0.904</td>
<td>RMSE 0.301</td>
<td>MAE 0.059</td>
<td>R² 0.989</td>
<td>RMSE 0.378</td>
<td>MAE 0.037</td>
<td>R² 0.997</td>
<td>RMSE 0.293</td>
</tr>
<tr>
<td>SVM5</td>
<td>R² 0.979</td>
<td>RMSE 0.205</td>
<td>MAE 0.038</td>
<td>R² 0.998</td>
<td>RMSE 0.350</td>
<td>MAE 0.034</td>
<td>R² 0.998</td>
<td>RMSE 0.434</td>
</tr>
</tbody>
</table>
indicate that pattern 5 in Zabol station has the highest value of $R^2$ (0.998) the least rate of error (RMSE = 0.434, MAE = 0.023). The results of three models in Zabol station show that the SVM model with the inputs of pattern 5 (SVM5) performs superior to the other models while the neuro-fuzzy model (ANFIS3) is identified as the second best model in estimating monthly potential evapotranspiration. Eventually, the GEP model with pattern 4 (GEP4) is ranked as the third one.

At Iranshahr station, the review of the results of the neuro-fuzzy models show that the ANFIS4 model has the highest level of coefficient of determination and the least RMSE, so it is introduced as the top model. The results of the GEP model in the station indicate that according to
the coefficient of determination, RMSE and MAE, pattern 4 (GEP4) has the highest accuracy. SVM model results indicate that pattern 5 (SVM5) in Iranshahr station has the highest $R^2$ (0.998) and the least RMSE (0.33) and MAE (0.034). Results of three models in Iranshahr station show that SVM with the input of pattern 5 (SVM5) is superior to the other models while GEP with pattern 4 (GEP4) is identified as the second best model in estimating monthly potential evapotranspiration. The neuro-fuzzy model (ANFIS2) is ranked in third place.

![Graphs of observed and predicted values of potential evapotranspiration using the best patterns of the GEP model at each station (all stations: pattern 4).](https://iwaponline.com/ws/article-pdf/19/2/392/592505/ws019020392.pdf)
Studying the model results shows that in Chabahar, ANFIS 3 which includes average air temperature, relative humidity, and wind speed inputs has a higher coefficient of determination with lower RMSE and MAE, so it is introduced as the best pattern. In addition, according to the values of the comparison criteria, the GEP model for pattern 4 (GEP4) has the highest accuracy. SVM model results indicate that among all patterns, pattern 5 in

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**Figure 4** | Graph of observed value of potential evapotranspiration and predicted ones using the best patterns of the SVM at each station (all stations: pattern 5).
Chabahar station has the highest coefficient of determination and the least MAE and RMSE. Reviewing the results of three models in Chabahar station shows that the SVM5 performs better than the others whereas the GEP4 is selected as the second best model. ANFIS2 is in third place. Comparison of the three methods shows that the SVM5 model has the highest accuracy for modeling monthly evapotranspiration.

Survey results of the neuro-fuzzy model show that when input parameters vary from 3 to 4 and even more, the coefficients of determination are low in the neuro-fuzzy models in most of the stations. In the SVM model, when all the variables are used as input for evapotranspiration modeling, the accuracy of the model is higher than the other models. This result is also in line with Goyal (2004) in which an SVM model was used to estimate potential evapotranspiration. Also, results of comparisons indicate that, \( \text{ET}_o \) predicted by GEP had higher accuracy in comparison with the ANFIS model. These results also correspond to the results of Shiri et al. (2012) and Terzi (2013).

Figures 2–4 show the graphs of potential evapotranspiration computed with the FAO-56 Penman-Monteith method and simulated values using the optimal ANFIS, GEP and SVM models. Superior accuracy of ANFIS, GEP and SVM models are clearly seen from the scatterplots and time variation graphs. Figure 5 compares the models estimates of monthly average \( \text{ET}_o \) values for the test period. In all stations, the SVM model closely follow the potential \( \text{ET}_o \) values while the ANFIS model cannot adequately estimate the Iranshahr and Chabahar stations. For Zabol station, the estimates of the models are very close to each other. For Chababar station, the GEP model cannot catch the \( \text{ET}_o \) of February-March and September-October while the SVM has bad estimates only for September and November. The ANFIS model can catch only \( \text{ET}_o \) of January, July and December out of 12 months.

**CONCLUSION**

In this study, the accuracy of ANFIS, SVM, and GEP models was assessed to estimate monthly potential evapotranspiration in Sistan and Baluchistan Province. To this end, temperature, sunny hours, relative humidity, and wind speed data were selected as the input parameters of the models and the amounts of monthly potential evapotranspiration were used as the output. The estimated values of each model were compared with the calculated amounts of potential evapotranspiration using the FAO Penman-Monteith method. The model evaluations were conducted using the coefficient of determination, RMSEs and MAEs. Modeling was conducted for four synoptic stations in Zahedan, Zabol, Iranshahr, and Chabahar using monthly data for the period 1964–2010. The results of the applied methods indicated that each method provided various levels of accuracy in all the stations. The main reason for this may be the fact that the stations are situated in different locations and have various climatic characteristics.
Comparison of results showed that in the stations of Zahedan, Zabol, Iranshahr, and Chabahar, the SVM model including average air temperature, relative humidity, wind speed, and sunny hours of the current and previous month has higher accuracy than the ANFIS and GEP models in estimation of potential evapotranspiration. In some cases, the applied models provided accurate results even though they used limited data. For example, the ANFIS3 and ANFIS2 models in Zabol and Zahedan, the GEP2 model in Iranshahr, Zabol and Zahedan, and the SVM3 model in Zabol and Zahedan stations. These models can be successfully applied in regions where relative humidity and sunny hours data are not available.

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