



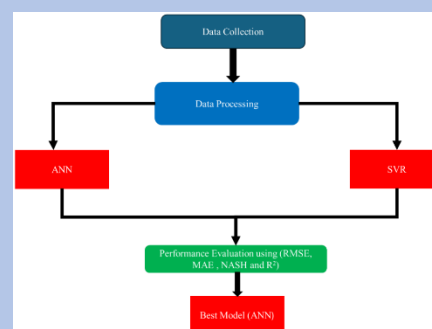
Estimation of Evaporation Rate Using Advanced Methods

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Abstract: One of the hydrological components of the cycle is evaporation, which has actual quantities that are challenging to quantify in the field. As a result, estimations of the evaporation rate's value are made using empirical relationships derived from data on climate components. Several applications of water resources, including hydrological, hydraulic, and an optimal agricultural irrigation system, depend heavily on accurate estimation of evaporation losses. Accurately estimating and forecasting hydrological phenomena is thought to be one of the most critical aspects of managing and developing water resources, as well as creating future water plans that consider various climate change scenarios. The Artificial Neural Network (ANN) and Support Vector Regression (SVR) methods are cutting-edge models that have been employed in several recent research to estimate various hydrological parameters. In the current study, the evaporation rate of Haditha Dam Lake on the Euphrates River in the Al-Anbar Governorate, Iraq, was predicted using ANN and SVR methods. It was designed to receive daily meteorological data, such as temperature, sunshine duration, wind speed, and humidity levels. Evaporation was chosen as the network's output. The present study presented several input scenarios with different input variables to examine the performance of the proposed models. Several statistical indicators have been used to evaluate the prediction results which are root mean square error (RMSE), Nash-Sutcliffe efficiency (NSE), mean absolute error (MAE), and correlation (R^2) the prediction accuracy. The outcomes demonstrated that ANN could predict evaporation value with a high degree of accuracy better than the SVR method. The best prediction model achieved high correlation and mean error between actual and predicted data.



Keywords: Evaporation, Data-driven model, hydrology.

Introduction

Iraq and most other countries in arid or semi-arid regions struggle with a lack of water resources for diverse uses (1,2). These nations' growing populations and the effects of climate change have increased the frequency of their droughts, which has reduced the amount of water available for use (3–6). As a result, these nations must manage and utilize their water resources as best they can (7,8). For sensible water resource management, the amount of water revenues has to be calculated and compared to the entire amount of water demand, together with the amount of losses, which include transpiration and evaporation (9–13). The practical of evaporation is one of the essential elements of the natural hydrological cycle phenomenon. One of the key components that the decision-maker needs in order to estimate the agricultural, industrial, and environmental plans as well as the water budget is the depth of evaporation (14–18). Evaporation from bodies of water, such as lakes, can be determined using several direct or indirect methods. One of the direct methods is the pan evaporation of several kinds. Numerous equations, including the Penman equation and Blaney-Cridle equations, have been produced by researchers from various parts of the world.

In fact, the Penman method is unsuitable for arid regions due to its reliance on intermittent large water usage, which poses a challenge in these areas. Additionally, The Blaney-Cridle method may not be suitable for large bodies of water, such as

Haditha Lake which is a case study. This is because the Blaney-Cridle equation relies primarily on temperature and does not consider the impact of wind, humidity, or local weather conditions, all of which significantly affect evaporation rates.

Researchers have employed various alternative techniques to gauge the amount of evaporation from water bodies due to the advancement and speed of computers. In (19), an evaporation simulation was created and assessed, and the effectiveness of a hybrid model was utilized to estimate the mean daily evaporation in northern Iran at the Talesh meteorological station. Two plants in Iraq had their monthly evaporation loss estimated using sophisticated machine learning algorithms (20), where the monthly climate data were utilized as inputs to replicate the monthly depth of evaporation.

1.1 Objectives

The present study introduced a robust prediction method based on data-driven models. The proposal model is applied to predict daily evaporation rate parameters. The research tried to discover the effect of the two different meteorological parameters on the prediction results. Therefore, daily temperature and relative humidity were utilized to investigate reliable prediction results. A comprehensive comparison has been made between two different models.

Case Study

With a storage capacity of 8.28 billion m³, Haditha Lake and Dam is situated 7 kilometers ahead of Haditha City on the

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Euphrates River in the Anbar Governorate (1). The dam measures 57 meters in height, 8933 meters in length at its peak, 386 meters in breadth at its base, 20 meters at its top, and 154 meters above sea level (21,22). The dam lake spans 503 square kilometers and has an operational level of 147 meters.

With a reservoir size of 575 square kilometers and a storage volume of 10.0 billion m³, the emergency level of the flood is 150.2 m (23–25). The Haditha Dam meteorological station has a Class A evaporation pan to record daily data on temperature minimums and maximums, relative humidity, wind speed, solar radiation, and evaporation depth.



Figure 1: Haditha Lake which is located on Euphrates River in Iraq.

Methodology

3.1 Artificial Neural Network (ANN)

An artificial neural network (ANN) is made up of several simple parts that function together (26,27). Connections and communication channels between these components frequently convey numerical data or weight. The units only utilize internal data and inputs obtained through connections in order to function. The field of artificial neural networks (ANN) is primarily motivated by the goal of developing artificial systems that are able to do sophisticated computations, much like the human brain (28,29).

A structured learning rule that adjusts the connection weights according to input/output data should be a part of an ANN (30,31). Or, to put it another way, an ANN exhibits strong representational capability outside of the training set and learns given instances (of well-known input/output sequences). ANN usually has great potential for parallelism because the component calculations are essentially independent of each other (32). Because they can tolerate certain errors and have access to a wealth of training data, artificial neural networks (ANN) are especially useful in real-world applications for problems involving categorization and function interpolation

methods (33,34). The artificial neural network method's architecture is displayed in Figure 2.

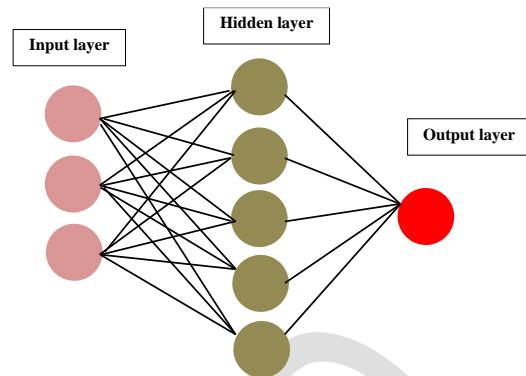


Figure 2: The structure of artificial neural network method.

2.2 Support vector regression:

Support vector regression (SVR), which was introduced by (35) based on the theory of statistical learning, is a set of supervised learning methods used for classification and regression tasks. SVR is a popular technique for prediction, pattern recognition, classification, regression, and function approximation (36,37). (38) introduced SVMs for dividing a set of vectors into two classes. SVMs are based on a hyperplane in the form of $w \cdot X + b = 0$ that optimally separates a set of n -dimensional vectors ($X_i \in R^n$) into two categories. This optimal hyperplane has the farthest distance from support vectors and the nearest data points from each class. Finding w is equivalent to solving a quadratic programming problem. To solve this problem, a trade-off parameter ($c > 0$) needs to be determined. To categorize vectors that are not linearly separable, a kernel function such as degree polynomial, radial basis, or hyperbolic tangent is used to map the observed multidimensional vectors to a space with higher dimensions (39). The following radial basis function was used:

$$k(X_i, X_j) = \exp(-\gamma \|X_i - X_j\|^2) \quad (1)$$

Where $\gamma > 0$ is the parameter of the kernel and X_i, X_j represents feature vectors in some input space. The nonlinear regression version of SVMs is written as follows:

$$y = \sum_{i=1}^m (g_i - g_i^*) k(X_i, X_j) + b \quad (2)$$

Where m indicates the total number of input data; g_i and g_i^* are the Lagrange multipliers for upper and lower constraints, respectively, and k denotes the kernel function employed to map the n -dimensional input vectors. There are some fundamental kernel functions provided by support vector machines such as linear, polynomial, sigmoid, and radial basis functions. Among these functions, the radial basis function (RBF) was used by some researchers (39), and the RBF kernel was selected for this study. Figure 3 shows the structure of the SVR model.

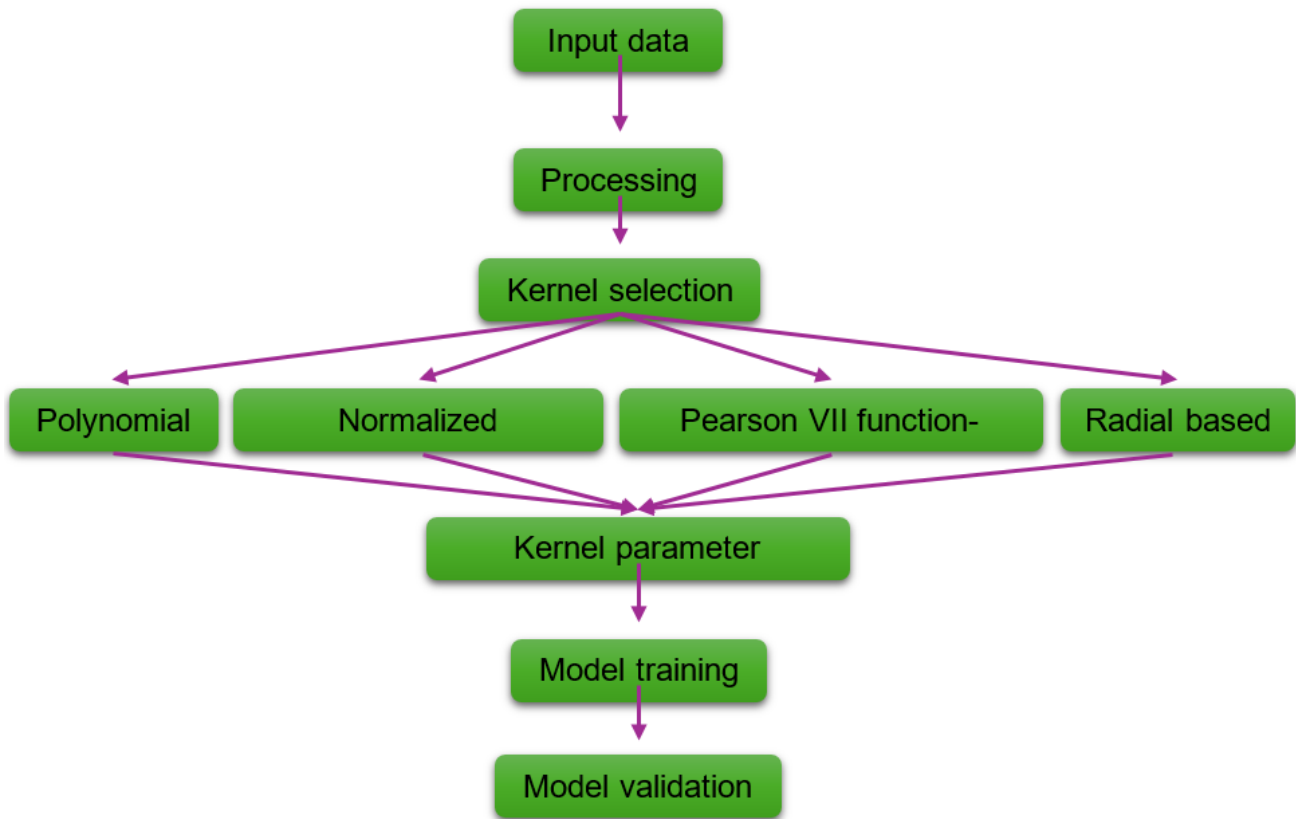


Figure 3: The structure of the support vector regression method.

Results and Discussion

Predicting the evaporation rate has been done using the Artificial Neural Network (ANN) approach. Four distinct architecture models were created to investigate the predictive model's effectiveness with various input variables. The architecture of the evaporation prediction models with ANN and SVR methods are expressed as the following:

$$\text{Model 1 : } (E_f = E_a(t - 1)) \quad (3)$$

$$\text{Model 2 : } (E_f = E_a, T_a) \quad (4)$$

$$\text{Model 3 : } (E_f = H_a, T_a) \quad (5)$$

$$\text{Model 4 : } (E_f = E_a, H_a, T_a) \quad (6)$$

Where E_f = the predicted evaporation value, E_a = actual evaporation, H_a = actual humidity, and T_a = actual temperature.

The accuracy of the evaporation prediction is displayed in the table. The (M4) model was the least accurate model, obtaining the highest values of RMSE (0.86) and MAE (0.69),

also the lowest value of NASH = 0.81. Nonetheless, the ANN approach produced very good prediction results when the second model's structure was considered.

Table 1 lists the ANN model's evaluation performance metrics.

Model No.	RMSE	MAE	NASH
M 1	0.44	0.34	0.86
M 2	0.41	0.29	0.94
M 3	0.86	0.62	0.83
M4	0.86	0.69	0.81

Figure 4 presents a comparison of model performance based on the correlation coefficient indication. The outcomes showed adequate prediction accuracy offered by models 1 and 4. In contrast, model 2 was able to attain a high degree of correlation between the actual and anticipated evaporation data. Compared to the other models, the Artificial Neural Network (ANN) approach using the (M2) model is a more trustworthy forecasting procedure.

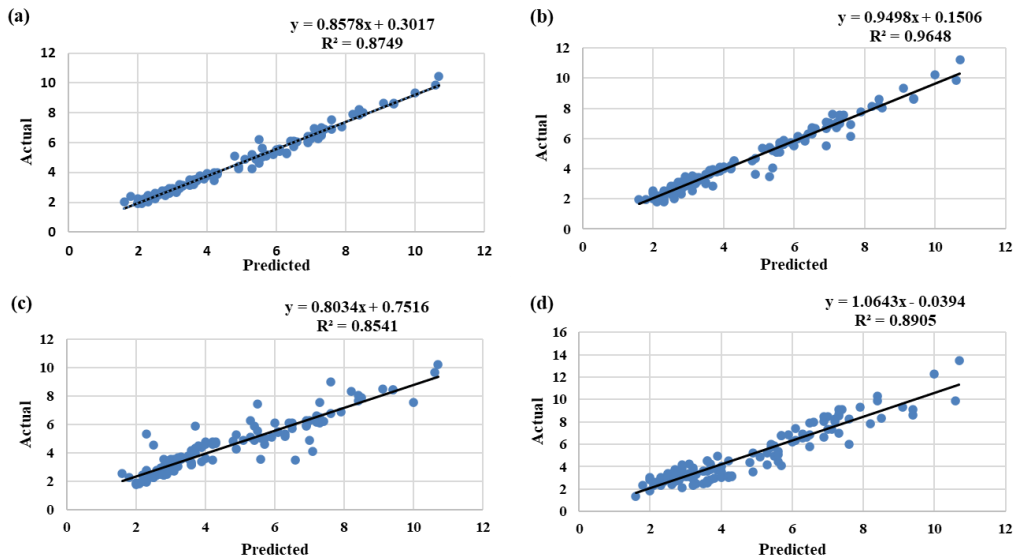


Figure 4: The correlation coefficient indicator for each proposed model based on the ANN method.

Support Vector Regression has also been employed to predict the monthly evaporation rate. The performance of the proposed model was examined with different input variables. The prediction results based on several indicators are presented in Table 2. The evaluation indicators showed that Model-2 achieved a minimum RMSE value between actual and predicted data. The higher RMSE value was obtained by Model-4 as shown in the Table. The prediction results indicated that Model-4 can provide high level accuracy compared to other models.

Table 2 lists the SVR model's evaluation performance metrics.

Model No.	RMSE	MAE	NASH
M 1	0.62	0.44	0.82
M 2	0.57	0.35	0.90
M 3	0.92	0.66	0.78
M4	0.93	0.72	0.77

Correlation between actual and predicted data during the testing period using SVR method is presented in Figure 5. The correlation magnitude was calculated for each proposed model (i.e., Model-1 to Model-2). The lowest correlation has been attained using Model-4. It can be seen that the results of Model-1 and Model-3 are relatively close. The prediction results indicated that high prediction accuracy can be obtained with Model-2.

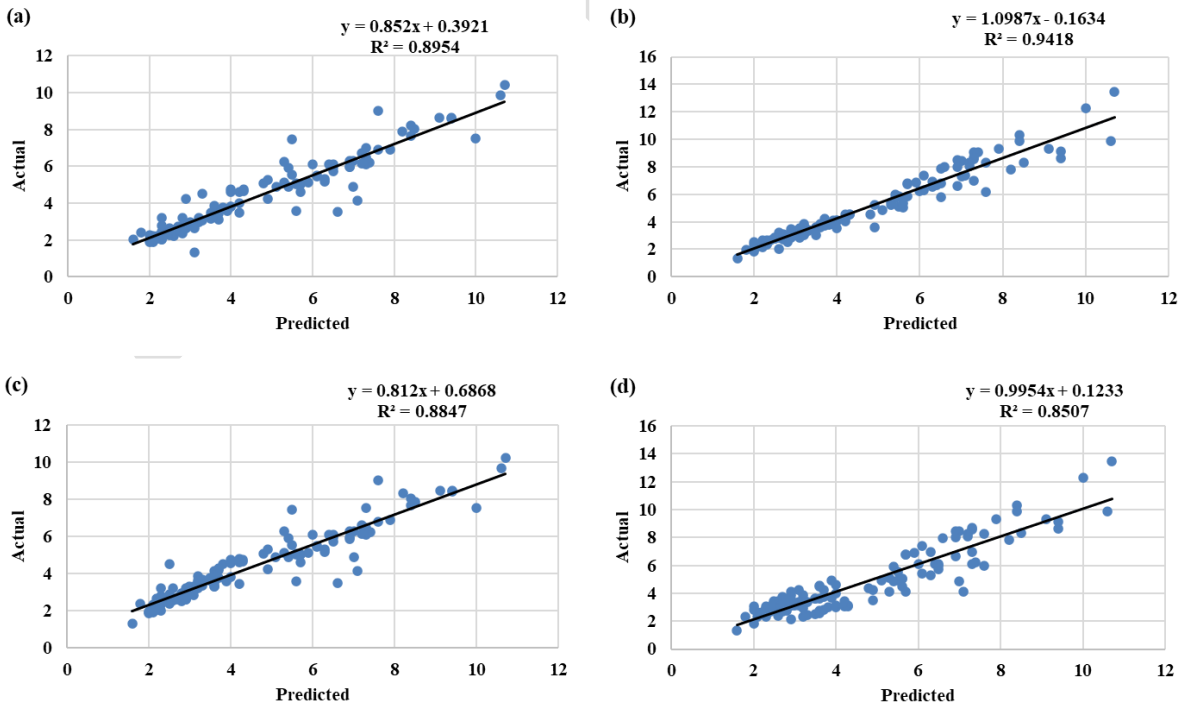


Figure 5: The correlation coefficient indicator for each proposed model based on the SVR method.

Conclusion

Based on data inputs from meteorological stations, this study discovered that the (ANN) model created had good accuracy and prediction of the daily evaporation from Haditha Lake's values. In order to create an efficient model that can be used to estimate the daily evaporation rate in the Governorate of Anbar with a high degree of accuracy, the study suggests testing the (ANN) model developed using climatic data gathered from all Al-Anbar governorate meteorological stations. The research suggests that decision-makers and water resource managers should utilize artificial neural network models to predict evaporation and manage water scarcity. Moreover, the proposed model can enhance irrigation scheduling, oversee water resources, and assess water quality.

Disclosure Statements

- Ethical Approval: The manuscript is conducted within the ethical manner advised by the targeted journal.
- Consent for publication: Not applicable.
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- Author's contribution: First author: Write the original manuscript, Second and third author: Formal analysis and investigation and Fourth author: Review and editing.
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