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# Proposing a Hybrid Method (Artificial Neural Networks - ARIMA) to Predict Temperatures in the City of Baghdad

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**Abstract:** Statistical methods and artificial intelligence play an important role in building models that can predict time series and thus help in developing strategic plans. The study aimed to propose a hybrid model (ARIMA and artificial neural networks) to predict the temperature in the city of Baghdad and compare it with the AA and N models based on the temperatures in the city of Baghdad for the period from January 2017 to December 2021. By comparing these models using forecast accuracy measures MAE, MSE, and MAPE, it was found that the hybrid method gives lower error values than ARIMA models and artificial neural networks, as it addresses the problem of non-linearity in the data, so it was relied upon to predict temperatures in the city of Baghdad for the next six months.

**Keywords:** artificial neural networks, temperature prediction, autoregressive integrated moving average, partial autocorrelation function.

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## Introduction

Economic and social sectors are affected by climate change. Many countries have suffered in previous years from natural disasters that led to material and human losses [1]. Therefore, interest has increased in the issue of predicting natural phenomena, temperatures, rainfall, storms, etc., to prepare for climatic events well before they occur. However, providing reliable seasonal forecasts is a concern for meteorologists [2]. Time series forecasting is considered one of the most important analysis methods. The methods used in time series forecasting vary. Some methods may be statistical, rely on artificial intelligence, or rely on the two methods by hybridizing them. Through our research, we will try to predict each of the previous methods and compare them to choose the best one to predict the future [3]. The aims of the research to predict temperatures in the city of Baghdad using a proposed hybrid model based on both the ARIMA model and the artificial neural network model [4].

The historical approach was adopted to study the fluctuations in temperature during the period 2017-2021, and the analytical approach was adopted using the ARIMA method, artificial neural networks, and the hybrid method to predict temperatures in the city of Baghdad, using the Spss, reviews, Matlab program to analyze data on the computer [5].

## Box-Jenkins

The Box-Jenkins method was first introduced in 1976 by Jenkins-Box. It is a time series analysis that takes into account the four parts of the AR model. These include the current values and the previous values. The MA is a representation of the time series whose value can be obtained through random errors in the present and past periods. The previous two models of the time series, the moving average and the autoregressive, can be used together to form the ARIMA. This is a composite model that takes into account all the necessary differences to make the series stable. The degree of the autoregression, the number of differences, and the degree of the averages are shown in the diagram below. The goal of the Box Jenks method is to maintain the stability of the period. It takes into account the various changes in the time series and adjusts them according to the general trend. The difference method is used to smooth the series by taking the values of each time series and varying them in a specific order. The definition phase of the model begins after ensuring that the time series is stable. It involves

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collecting information about the model parameters p, q, and d through the use of the PACF and ACF autocorrelation functions. The next step is to determine the model's parameters by taking into account the time series observations' values. This is done through the use of various methods, such as the non-linear least squares, momentum, and potential function methods. The close models that are estimated are then compared and selected based on the best one. After the model has been accepted, it undergoes various tests to make sure that it does not have an autocorrelation between its errors and the residuals. The values are then predicted using the new model.

**Artificial neural networks:** The steps to follow are outlined in the MATLAB program and the tool:

1. Data entry: The data entry process is carried out.

2. Input the desired output beam Target Data.

3. Divides the dataset into three parts. The training phase comprises 70% of the data, which is spent training the network until it enters the stability stage. This stage involves adjusting it according to the error, which lowers the MSE error to the value specified in the significance range of 0.05. The network then passes the stability stage and is ready for the subsequent testing phase.

- The testing phase comprises 15% of the sample size. This is the portion of the output that the network takes into account when determining its results.
- The training phase involves handling 70% of the dataset. As the network enters the stability stage, it undergoes adjustment to reduce the error value to the value indicated in significance range 0.05. This phase is completed and the network is ready to proceed with the subsequent test.

4. Select the type of neural network that will be utilized for prediction.

5. The training algorithm and the error measure for the network to be used must be chosen:

- The chosen error measure is known as MSE, which is a standard that's commonly used in neural networks. It can also deal with other metrics such as RMSE.
- The two training algorithms that are used in MATLAB are the TRAINLM and the TRAINBR. The former is a backward learning algorithm, while the latter is a regularization algorithm.

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- The network training algorithm used is the TRAINBR and the TRAINLM from the program options in MATLAB. The latter is a backpropagation algorithm that uses error-backward learning. It adjusts the weights and biases according to the method used by Levenberg-Marquardt. The other option is the regularization Bayesian algorithm.

  6. The steps leading to the achievement of results are enumerated below:

- Calculated output.
- Before a network training process can be carried out, an error measure should be assigned, and this can be adjusted according to the application being used.

## RESULT AND DISCUSSION

### Predicting temperatures in the city of Baghdad using a model SARIMA

The study is the predict the temperature in Baghdad using the data collected from the period 2017 to 2021, as shown as in Table (1).

Table (1): shows the monthly temperature in Baghdad from 2017 to 2021.

| 2021 | 2020 | 2019 | 2018 | 2017 | month |
|---|---|---|---|---|---|
| 11.6 | 11.1 | 11.1 | 11.9 | 9.7 | January |
| 14.2 | 13.2 | 12.9 | 15.1 | 10.5 | February |
| 18.7 | 18.6 | 16 | 21.3 | 17.7 | March |
| 25.5 | 23.8 | 21 | 23.3 | 23.5 | April |
| 32.2 | 30.1 | 30.6 | 29 | 30.5 | May |
| 35.4 | 33.9 | 36.1 | 34.3 | 34.5 | June |
| 37.8 | 38.5 | 35.9 | 36.2 | 38.6 | July |
| 36.6 | 34.8 | 36.6 | 35.5 | 38.1 | August |
| 31.2 | 33.7 | 32.6 | 32.8 | 33.9 | September |
| 25.6 | 25.7 | 26.9 | 26.9 | 25.8 | October |
| 18.2 | 18.8 | 17.6 | 17 | 18.5 | November |
| 12.3 | 12.3 | 13.1 | 13 | 13.7 | December |

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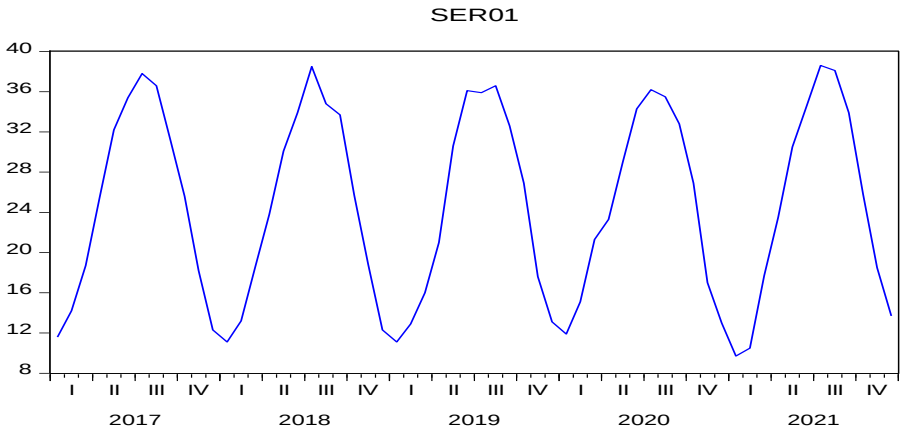


Figure (1): shows the changes in the monthly temperature from 2017 to 2021.

From Figure (1), it is clear that there are seasonal fluctuations, but the general trend does not appear, which means that the series is stable.

**Studying the characteristics of the distribution of the values of the original series:**

Before starting to find the optimal model, it is necessary to test the original series if it has the characteristics of a normal distribution, as the results appear in Figure (2):

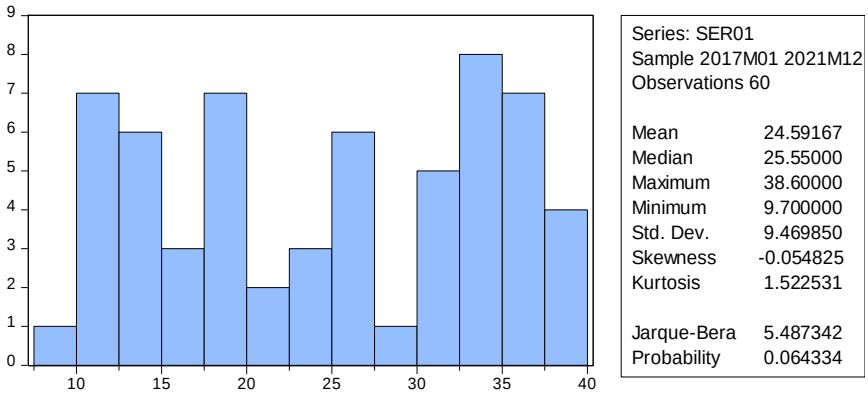


Figure (2): value of the Jarque-Bera test

It is clear from the previous figure that the calculated value of the Jarque-Bera test index is JB = 5.487342 and that the significance probability value of 0.064334 is greater than the value of the significance level of 0.05. Therefore, we accepted the assumption of a normal distribution for the original series with a significance level of 5%, meaning that it is normally distributed.

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**Study of stability:**

The stability exhibited by the series during our study was confirmed by our graphical representation. To determine if the unit root is present, we performed an augmented-dicky-fuller analysis to investigate the matter. The results of our investigation, which were shown in Table 2

Table 2: Results of the extended Dickey-Fuller test on temperature data in Baghdad

| Model type | Calculated value t | Tabular value ADF | Sig. |
|---|---|---|---|
| With constant and general trend | -6.102308 | -2.918778 | 0.000 |
| With constant | -6.060452 | -3.498692 | 0.000 |
| Without constant and general trend | -0.180294 | -1.947665 | 0.6161 |
| first difference | | | |
| With constant and general trend | -6.204934 | --2.923780 | 0.000 |
| With constant | -6.151509 | -3.506374 | 0.000 |
| Without constant and general trend | -6.291557 | -1.947816 | 0.000 |

Source: Prepared by the researcher based on the E-Views program.

It is clear from Table (2) that the calculated values for this test (with a constant and with a general trend, with a constant, without a constant, and a general trend) are greater than the tabulated values at the 5% level of significance, and the value of the probability of significance Prob. If this test is greater than 0.05 we accept the null hypothesis of the extended Dickey-Fuller test which states that the time series has a unit root and is therefore unstable. To make the series stable, we took the first-order differences to eliminate the general trend and re-ran the stability test. It is clear from Table (2) that the calculated values for this test after taking the first difference (with a constant and with a general trend, with a constant, without a constant and a general trend) are smaller than the tabulated values at the 5% level of significance, and the probability of significance value Prob. For this test, it is smaller than 0.05, so we reject the null hypothesis of the extended Dickey-Fuller test, which states that the time series has a unit root and is therefore stable. Thus the series becomes stable after taking the first difference.

Diagnosing and determining the rank of the model: To reach the model that gives the best representation of the time series, a group of models was proposed and the best of them was

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selected based on choosing the lowest value for the following metrics (Aikiki AIC, Hanan Quinn HQ, Schwartz BIC, logarithm of greatest potential LogL) as shown in the table (3):

Table 3: Comparing the proposed models according to the proposed standards model's parameters and some of its statistical indicators.

| Model Selection Criteria Table<br>Dependent Variable: LOG(SER01)<br>Date: 11/28/23 Time: 23:08 Sample: 2017M01 2022M12<br>Included observations: 60 | | | | |
|---|---|---|---|---|
| Model | LogL | AIC* | BIC | HQ |
| (3.4)(1.2) | 75.884304 | -2.129477 | -1.710608 | 1.965634 |
| (2.1)(1.1) | 70.374195 | -2.112473 | -1.868133 | -2.016898 |
| (2.2)(1.1) | 71.043744 | -2.101458 | -1.822212 | -1.992230 |
| (2.1)(1,2) | 70.786792 | -2.092893 | -1.813647 | -1.983665 |
| (5.2)(0.0) | 71.783088 | -2.092770 | -1.778618 | -1.969888 |
| (4.1)(1.2) | 72.780380 | -2.092679 | -1.743622 | -1.956144 |
| (5.0)(1.2) | 72.704879 | -2.090163 | -1.741105 | -1.953627 |
| (6.4)(1.2) | 77.658933 | -2.088631 | -1.565045 | -1.883828 |
| (4.0)(1.2) | 71.650735 | -2.088358 | -1.774206 | -1.965476 |
| (2.2)(1.2) | 71.638012 | -2.087934 | -1.773782 | -1.965052 |
| (2.2)(2.1) | 71.438737 | -2.081291 | -1.767140 | -1.958409 |
| (3.1)(1.2) | 71.405238 | -2.080175 | -1.766023 | -1.957293 |
| (2.5)(1,0) | 72.299320 | -2.076644 | -1.727587 | -1.940108 |
| (2.3)(1,1) | 71.263851 | -2.075462 | -1.761310 | -1.952580 |
| (5.1)(1.2) | 73.178308 | -2.072610 | -1.688647 | -1.922421 |
| (5.3)(0.0) | 72.141974 | -2.071399 | -1.722342 | -1.934864 |
| (2.4)(1.1) | 71.995080 | -2.066503 | -1.717445 | -1.929967 |
| (3.4)(1.1) | 72.916553 | -2.063885 | -1.679922 | -1.913696 |
| (5.1)(1.1) | 71.807446 | -2.060248 | -1.711191 | -1.923713 |
| (4.2)(1.1) | 71.763004 | -2.058767 | -1.709709 | -1.922231 |
| (2.4)(1,2) | 72.688451 | -2.056282 | -1.672319 | -1.906093 |
| (5.2)(1.2) | 73.687723 | -2.056257 | -1.637389 | -1.892415 |
| (4.0)(2.2) | 71.624563 | -2.054152 | -1.705095 | -1.917617 |
| (6.2)(1.1) | 73.578032 | -2.052601 | -1.633732 | -1.888758 |
| (3.6)(2.2) | 76.551050 | -2.051702 | -1.528116 | -1.846899 |
| (3.2)(1.2) | 71.501382 | -2.050046 | -1.700989 | -1.913511 |
| (4.2)(1.2) | 72461928 | -2.048731 | -1.664768 | -1.898542 |
| (6.2)(1.0) | 72.393614 | -2.046454 | -1.662491 | -1.896265 |
| (3.2)(2.1) | 71.338377 | -2.044613 | -1.695555 | -1.908077 |
| (5.4)(1,1) | 74273766 | -2.042459 | -1.588684 | -1.864963 |
| (6.3)(0.0) | 72.250613 | -2.041687 | -1.657724 | -1.891498 |

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Table (4): model's parameters and its statistical indicators.

Dependent Variable: LOG(SER01)
Method: ARMA Maximum Likelihood (BFGS)
Date: 11/28/23 Time: 23:08
Sample: 2017M01 2021M12
Included observations: 60
Failure to improve objective (non-zero gradients) after 45 iterations
Coefficient covariance computed using outer product of gradients

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 3.115660 | 0.013581 | 229.4164 | 0.0000 |
| AR(1) | 0.734469 | 0.001789 | 410.5482 | 0.0000 |
| AR(2) | 0.734080 | 0.001749 | 419.6503 | 0.0000 |
| AR(3) | -0.999793 | 0.000752 | -1329.939 | 0.0000 |
| SAR(3) | -0.999996 | 0.000119 | -8425.905 | 0.0000 |
| MA(1) | -0.331028 | 0.109020 | -3.036411 | 0.0039 |
| MA(2) | -0.972469 | 0.084421 | -11.51930 | 0.0000 |
| MA(3) | 0.734100 | 0.105550 | 6.954998 | 0.0000 |
| MA(4) | 0.375554 | 0.126217 | 2.975468 | 0.0046 |
| SMA(3) | 0.945088 | 0.214124 | 4.413735 | 0.0001 |
| SMA(6) | -0.051591 | 0.212788 | -0.242450 | 0.8095 |
| SIGMASQ | 0.003504 | 0.001410 | 2.485590 | 0.0165 |

| | | | |
|---|---|---|---|
| R-squared | 0.980697 | Mean dependent var | 3.118230 |
| Adjusted R-squared | 0.976273 | S.D. dependent var | 0.429660 |
| S.E. of regression | 0.066183 | Akaike info criterion | -2.123531 |
| Sum squared resid | 0.210250 | Schwarz criterion | -1.704662 |
| Log likelihood | 75.70594 | Hannan-Quinn criter. | -1.959689 |
| F-statistic | 221.6922 | Durbin-Watson stat | 1.942199 |
| Prob(F-statistic) | 0.000000 | | |

| | | | | |
|---|---|---|---|---|
| Inverted AR Roots | .87+.50i | .87-.50i | .50+.87i | .50-.87i |
| | -1.00 | -1.00 | | |
| Inverted MA Roots | .85+.52i | .85-.52i | .50+.87i | .50-.87i |
| | .37 | -.19+.32i | -.19-.32i | -.38 |
| | -1.00 | -1.00 | | |

Source: E-VIEWS program outputs

From Table (4), we find that the model is significant because the test value F =221.6922 the probability value of the test is 0.000, and the model explained the total variance by 98.0697%.

**Testing the hypotheses of the model:**

To ensure that there is no autocorrelation of the residuals, we used the autocorrelation and partial autocorrelation functions for the residuals, as shown in Figure (3):

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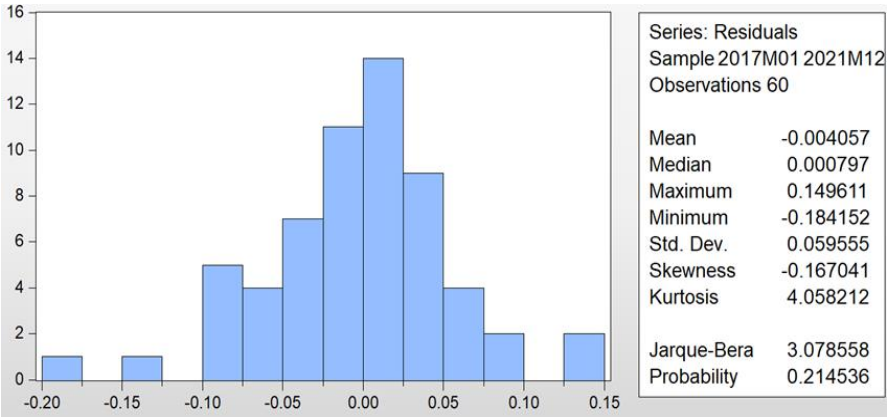


Figure 3: value of the Jarque-Bera test normal distribution of the residuals

It is clear from Figure (3) that the series of residuals is stable since the autocorrelation coefficients all fall within the confidence range. To test the normal distribution of the residuals, we used the Kolmogorov-Smirnov test, the results value of the Kolmogorov-Smirnov statistic was 3.078558, and the value of the probability of significance was Prob. = 0.214536 is greater than the significance level of 0.05, and therefore the assumption of a normal distribution of the residuals was accepted. These tests confirm that the proposed model is suitable for prediction.

**Predicting monthly temperatures in the city of Baghdad using artificial neural networks:**

The kind of artificial neural network is utilized for forecasting was chosen from the (networks) menu in the MATLAB program, where artificial neural networks (Layer Recurrent Networks (LRN)) were used to predict time series while changing the number of hidden layers in these networks (one hidden layer, Two hidden layers, etc.) The number of neurons in these layers was also changed, and all types of linear, logarithmic, and angular transformation functions were used in the hidden and outer layers, relying on the training algorithms TRAINLM and TRAINBR. The white noise and weights generated by the program are randomly chosen. There were 12 networks created according to the various choices made by the program. The previous networks were then implemented, which resulted in the formation of 12 predictive time series. The most error-free network was selected based on the metrics of the error analysis performed by the three different error systems: the MAPE, MSE, and MAE.

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Table (5): Results of error measures for predictive time series

| | | | Layer Recurrent Network | | |
|---|---|---|---|---|---|
| Training function | Adaption learning function | transfer function | MAE | MAPE | MAP |
| LM | GD | login | 12.98513305 | 0.34249157 | 265.3300593 |
| | | purlin | 5.986666667 | 0.28459484 | 52.59066667 |
| | | tansig | 7.058690962 | 0.487079194 | 67.69915261 |
| | GDM | logsig | 9.390227646 | 0.29246698 | 121.4865903 |
| | | purlin | 20.69398994 | 1.409538786 | 471.9475217 |
| | | tansig | 14.79821926 | 1.516601642 | 308.1954573 |
| BR | GD | logsig | 6.324329892 | 0.413646817 | 69.1601041 |
| | | purlin | 10.58544451 | 0.312903073 | 158.0336813 |
| | | tansig | 16.25290664 | 1.554285889 | 343.237164 |
| | GDM | logsig | 13.58976389 | 0.354493922 | 272.3236356 |
| | | purlin | 13.96818257 | 0.362600902 | 282.2462719 |
| | | tansig | 14.88000809 | 1.532083163 | 309.5798178 |

Source: the based on the outputs generated by the MATLAB program.

Table (5) shows that the transformation functions that were used for the Layer recurrent network when it utilized the TRAINLM training procedure and the procedure had the fewest errors.

**Forecasting monthly temperatures in the city of Baghdad using hybrid methods**

The neural networks were fed the prediction result of the ARIMA model to eliminate the nonlinear component. The results were based on a Pearson artificial neural network, and SPSS was used to obtain the results Table (6) shows the MSE, MAE, and MAPE error values for each of the proposed models about the time series to choose the best MSE, MAE, MAPE error.

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Table (6): the error values of MSE, MAE, and MAPE

| | MSE | MAPE | MAE |
|---|---|---|---|
| MLP(1-1-1) | 1.522337 | 0.073658 | 1.007719 |
| MLP(1-2-1) | 1.430791 | 0.044145 | 0.963839 |
| MLP(1-3-1) | 1.510221 | 0.071366 | 0.99614 |
| MLP(1-5-1) | 1.518896 | 0.072354 | 1.000877 |
| MLP(1-10-1) | 1.582872 | 0.075228 | 1.015965 |

It is clear from Table (6) that the previous best model is MLP (1 − 5 − 1) because it has the lowest values of the error criteria compared to the other candidate models.

**Comparison between the artificial neural networks model, SARIMA, and hybrid models:** To compare between the three models, we relied on the evaluation criteria adopted in the research to choose the model that gives the lowest value of errors and thus has greater predictive ability in the future as shown in Table (7).

Table (7): Comparison results between the three models

| MODEL | MAP | MAPE | MAE |
|---|---|---|---|
| artificial neural networks | 52.59066667 | 0.38459484 | 5.986666667 |
| SARIMA | 1.50434 | 0.071365 | 0.996842 |
| hybrid models | 1.430791 | 0.044145 | 0.963839 |

From the previous table, we find that the values of the error measures for the hybrid models are lower than those for the SARIMA model and artificial neural networks, so This will be used in the forecasting process in the future. Table (8) shown the results of the city of Baghdad's temperature forecasting. until the end of 2022 using the hybrid model.

Table (8): Predictive values of temperatures using the hybrid method

| month | temperature | month | temperature |
|---|---|---|---|
| April | 25.77499132 | January | 12.63905013 |
| May | 33.13215452 | February | 13.84481668 |
| June | 37.20368314 | March | 19.08529788 |

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**Results and Recommendations:**

Through the applied study of time series analysis and using both SARIMA and artificial neural networks and the method of combining the two previous methods to predict temperatures in the city of Baghdad, the study reached the following most important results:

1. The time series of temperatures in the city of Baghdad was modeled using the artificial neural network model, SARIMA, and the hybrid method (networks and SARIMA).
2. The appropriate prediction model was chosen for each method by comparing the proposed models and selecting the best one based on the MSE criterion.
3. After choosing the best model for each method, a comparison was made between the three selected models.
4. Hybrid model was adopted to predict temperatures in the city of Baghdad, which gives the lowest error value for each of the criteria, MSE, MAE, and MAPE.

**Recommendations:**

1. We recommend that government agencies use the models we have obtained to predict temperatures in the city of Baghdad.
2. We recommend using fuzzy artificial neural networks to predict temperatures in the city of Baghdad
3. We recommend conducting a merger between artificial neural networks and other linear methods to predict temperatures in the city of Baghdad.

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