Journal of Computing Research and Innovation (JCRINN) Vol. 6 No. 1 (2021) (pp22-30)
https://jcrinn.com : eISSN: 2600-8793 / DOI: 10.24191/jcrinn.v6i1.170

Fuzzy Time Series and Artificial Neural Network: Forecasting Exportation of Natural Rubber in Malaysia

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Received Date: 18 November 2020
Accepted Date: 7 Mac 2021
Published Date: 14 Mac 2021

HIGHLIGHTS

- There are seven algorithms chosen in this study which are Quick Propagation, Conjugate Gradient Descent, Quasi-Newton, Limited Memory Quasi-Newton, Levenberg-Marquardt, Online Back Propagation and Batch Back Propagation.
- The smallest absolute error which is 6054.3744 by Limited Memory Quasi-Newton algorithm.
- The lowest value of MSE, RMSE and MAPE by using Fuzzy Time Series compared to Artificial Neural Network (ANN) Model.

ABSTRACT

Natural rubber is one of the most important crops in Malaysia alongside palm oil, cocoa, paddy, and pineapple. Being a tropical country, Malaysia is one of the top five exporters and producers of rubber in the world. The purpose of this study is to find the forecasted value of the actual data of the number of exportations of natural rubber by using Fuzzy Time Series and Artificial Neural Network. This study is also conducted to determine the best model by making comparison between Fuzzy Time Series and Artificial Neural Network. Fuzzy Time Series has allowed to overcome a downside where the classical time series method cannot deal with forecasting problem in which values of time series are linguistic terms represented by fuzzy sets. Artificial Neural Network was introduced as one of the systematic tools of modelling which has been forecasting for about 20 years ago. The error measure that was used in this study to make comparisons were Mean Square Error, Root Mean Square Error and Mean Absolute Percentage Error. The results of this study showed that the fuzzy time series method has the smallest error value compared to artificial neural network which means it was more accurate compared to artificial neural network in forecasting exportation of natural rubber in Malaysia.

Keywords: *Fuzzy Time Series, Artificial Neural Network, exportations of natural rubber, Mean Square Error, Root Mean Square Error, Mean Absolute Percentage Error*

INTRODUCTION

Natural rubber is one of the most important crops in Malaysia alongside the palm oil, cocoa, paddy, and pineapple. Being a tropical country, Malaysia is one of the top five exporters and producers of rubber in the world. According to Cornish (2017), tropical countries that were currently natural rubber supplies were vulnerable because global demand is increasing rapidly that led by the industrialization of developing countries, labour shortages and fungal crop diseases.

According to MdLudin, Applanaidu, and Abdullah (2016), one of the main contributors in Malaysia is the agricultural sector and it is also considered as one of the main contributors in Malaysia Gross Domestic Product (GDP) in 1980 with contribution around 22.9 percent. They also stated that the rubber has contributed around 39.8 percent in the agricultural sector in 1984. This shows that rubber is important to the agricultural sector as it is one of the biggest contributors in that sector. However, according to Department of Statistics Malaysia, the implementation of the Movement Control Order in this year has an impact to the establishment that carries out rubber processing activities. The production of natural rubber for this year is decreases compared to the last year. The techniques used in this study were Fuzzy Time Series and Artificial Neural Network. According to Cai, Zhang, Zheng and Leung (2015), fuzzy time series were first introduced by Song and Chissom in 1993. They also stated that the fuzzy time series have been proven that it can be appropriately applied to datasets of linguistic values to generate forecasting rules with high accuracy. Next, artificial neural networks are one type of network that see the node as artificial neurons and it is a software implementation that resembles the biological term central nervous system that is the human brain (Narvekar & Fargose, 2015).

The increasing of natural rubber, the rubber industry export earnings and the foreign exchange earnings will also increase the income of Malaysia. Since the natural rubber is one of the contributors to generate income in Malaysia this study aims to make a comparison between two model, which are forecasting the exportation of natural rubber Fuzzy Time Series and Artificial Neural Network. However, there is a variation in the monthly exportation of natural rubber statistics. This will lead to vagueness in the level of export earnings, foreign exchange earnings and it will affect the income of Malaysia too. Therefore, a precise forecasting model is needed to aid the government to predict the estimated value of the exportation of natural rubber. Besides, this study provides the comparison of model and selection to justify the best model between the Artificial Neural Network use and Fuzzy Time Series. The model evaluations which are MSE, RMSE and MAPE for each technique was identify. Absolute error of the seven algorithms of the training network output was obtained from Artificial Neural Network while the fuzzy logical relationship was developed in Fuzzy Time Series model.

The forecasting model also helps the government to make a felicitous plan to avoid losing the income, losing in export earnings and also losing in the foreign exchange earnings. Furthermore, recent studies by Fauzi, N. F., Nurul Shahiera Ahmadi, & Nor Hayati Shafii. (2020), forecasting at high precision becomes valuable since it may guarantee the development and the willingness of all tourism agencies such as hotels, transportation, food, and services industries. Other than that, the conducted study to seek out what is the best forecasting of the number of tourist arrival by comparing two methods, which are the Fuzzy time series and Holt-Winter.

Fuzzy Time Series modeling is based on fuzzy logic which is most suitable model to predict time series data. According to Güler Dincer and Akkuş (2018) formulated the fuzzy time series model to predicted the air pollution. The result showed that the Fuzzy Time Series model provide successful forecasting results specifically in time series and the predicted results than have been compared between Root Mean Square Error (RMSE) and Mean Absolute Percentage Error (MAPE) goodness of fit measures.

METHODOLOGY

Fuzzy Time Series

Step 1: All of the data were analyzed and then they were changed into percentage form. The formula is as shown below:

$$y_n = \frac{(y_n - y_{n-1})}{y_{n-1}} \text{x}100 \quad (1)$$

where;

y_n= number of exportations of the natural rubber

y_{n-1}=number of exportations of the natural rubber before

Step 2: There were two values that needed to be identified from the percentage of changes which were the minimum value and the maximum value. The universe of discourse (U) needed to be identified by using U= $[D_{min} - D_1, D_{max} + D_2]$ after identifying the two values. D_1 and D_2 represent two positive numbers that need to be assigned in U.

Step 3: The fuzzy sets U_i needed to be constructed within the same length of intervals where i equal to 1 until 7. The fuzzification of interval and the frequency distribution of each interval needed to be identified in this step. The length of interval for fuzzification is calculate as:

Length of interval = $\frac{(D_{max}+D_2)-(D_{min}-D_1)}{7}$ (2)

Step 4: The interval of v_1, v_2,…, v_n needed to be generated based on step 2. The interval needed to be done in the form of trapezoidal number. It can be represented as shown below:

A_1= $[b_o, b_1, b_2, b_3]$,

A_2= $[b_1, b_2, b_3, b_4]$,

A_3= $[b_2, b_3, b_4, b_5]$,

.

.

.

A_n= $[b_{n-1}, b_n, b_{n+1}, b_{n+2}]$

Step 5: All of the data were listed in terms of percentage and each data was classified based on the interval that has been generated in step 4. The fuzzy set A_i showed a linguistic value and if the data were founded in the range of v_j, then it would be a fuzzy number that was A_j. Then, fuzzy logical relationship needed to be generated based on the data that have been classified. Fuzzy logical relation is symbolized as shown below:

$A_i \rightarrow A_j$,

where A_i is presented in form and A_j is the future form.

Step 6: Based on the fuzzy logical relations in step 5, fuzzy logical relationship rule needed to be created. The fuzzy logical relationship rule needed to be arranged in groups.

Step 7: Each fuzzy relationship rule group should be classified into one of three different types of rule. The forecasted production for each group was different according to the rules set. The rules are as shown below:

Rule 1: The fuzzy group of A_j is empty which means A_j has no relationship rule others. It can be symbolized as $A_j \rightarrow \varnothing$ or it can also be represented as $A_j \rightarrow A_j$. The forecasted value formula for this rule is:

$$F_{vt} = R\,[NSTFN\,(A_j)]. \quad (3)$$

Rule 2: The fuzzy group of A_j is one to one which means there is only one relationship rule that is related to A_j and can be written as $A_j \rightarrow A_m$. The forecasted value is calculated as formula shown below:

$$F_{vt} = R\,[NSTFN\,(A_m)]. \quad (4)$$

Rule 3: The fuzzy group of A_j is one to many. The forecasted value is calculated as shown below:

$$F_{vt} = R\left[\frac{NSTFN(A_{m1}) + NSTFN(A_{m2}) + NSFTN(A_{m2})}{n}\right] \quad (5)$$

where n is the number of A_i in this group.

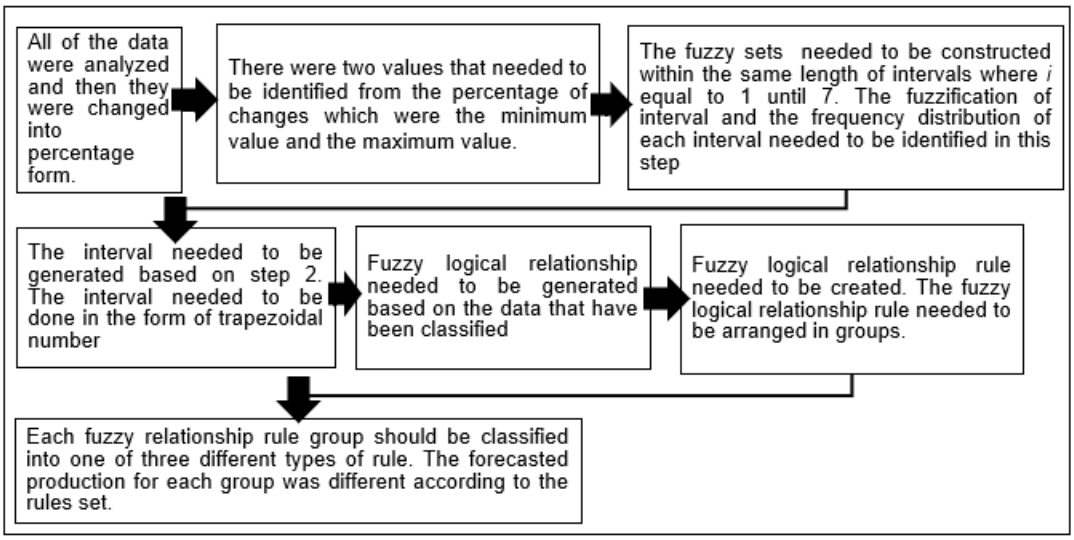

Figure 1: Step of Fuzzy Time Series

From Figure 1 above, shows all the seven steps in fuzzy time series from the actual data obtained to fuzzification process and grouped into three different type of rule fuzzy logical relationship.

Artificial Neural Network

The steps of using Alyuda NeuroIntelligence Software are shown in Figure 2 below. There are six steps to develop ANN using this software which are data analysis, data preprocessing, designing network, training network, testing network and querying network.

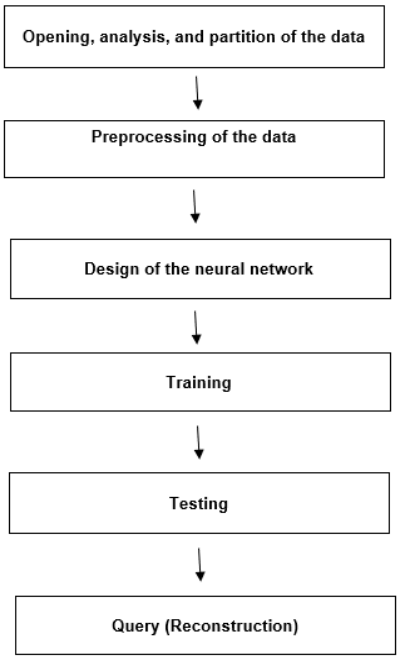

Figure 2: Steps of using Alyuda NeuroIntelligence Software

FINDINGS AND DISCUSSION

Fuzzy Time Series

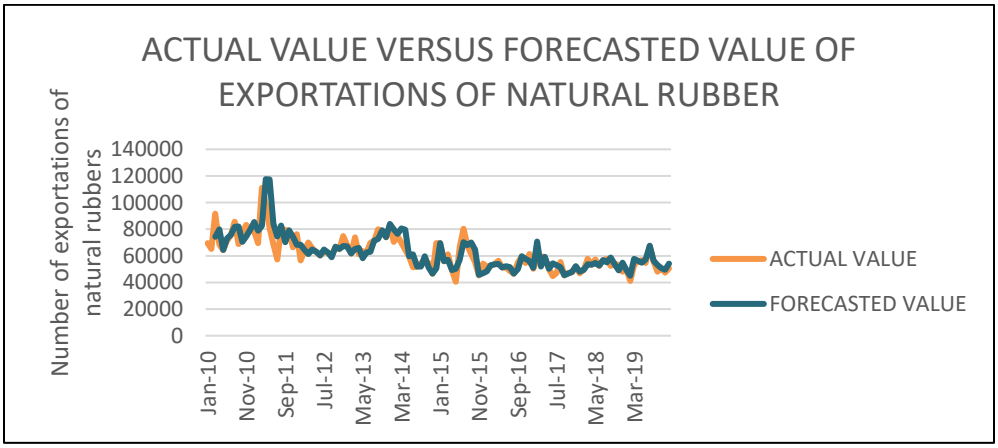

Figure 3: Actual value versus forecasted value of exportations of natural rubber from January 2010 to May 2019.

The Figure 3above shows the actual against forecasted value of exportation of natural rubber from January 2010 to May 2019.

Artificial Neural Network

There are seven algorithms that were compared by the absolute error. The Table 1 below shows the absolute error of the training network output of the 7 algorithms. Limited Memory Quasi-Newton algorithm has the smallest absolute error which is 6054.3744. Figure below shows the result of the network training.

Table 1: Absolute error of the algorithms of the training network output

Type of algorithms	Absolute error
Quick Propagation	6054.3862
Conjugate Gradient Descent	6116.9826
Quasi-Newton	6114.5047
Limited Memory Quasi-Newton	6054.3744
Levenberg-Marquardt	15104.3879
Online Back Propagation	6580.4901
Batch Back Propagation	9881.7004

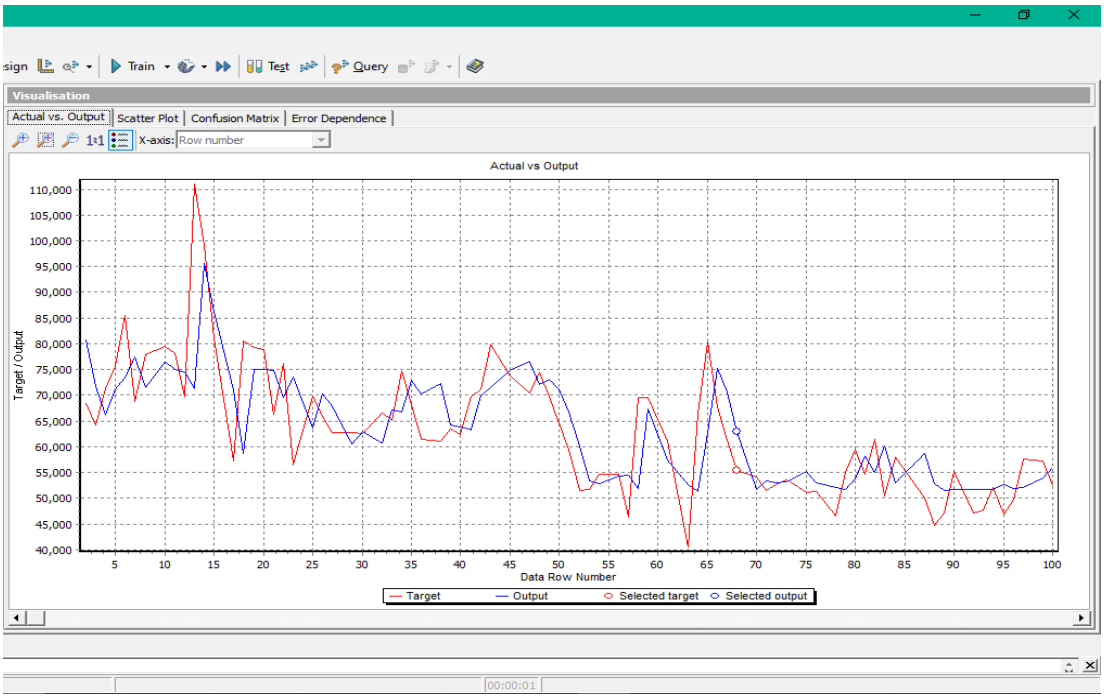

Figure 4: Graph of Actual versus Output based on Limited Memory Quasi-Newton

Figure 4 above showed the graph of actual data versus output data based on Limited Memory Quasi-Newton and the Table 3 below shows the summary table that contains the value of the target, output, absolute error (AE), absolute relative error (ARE), mean, standard deviation, minimum and maximum value based on Limited Memory Quasi-Newton.

Table 2: Summary table based on Limited Memory Quasi-Newton

	Target	**Output**	**AE**	**ARE**
Mean	63502.4815	63680.0424	6326.9094	0.0985
Std. Deviation	12448.3609	9944.8572	5720.0362	0.0749
Min	40512	51278.9074	198.5680	0.0038
Max	111020	95580.606728	39666.0426	0.3573

The Table 2 above shows the summary of the value of the target, output, absolute error (AE), absolute relative error (ARE), mean, standard deviation, minimum and maximum value based on Limited Memory Quasi-Newton.

Comparison of Models and Selection of The Best Model

The Table 3 below shows the comparison between the two models by using model evaluations which are MSE, RMSE and MAPE for Fuzzy Time Series and Artificial Neural Network.

Table 3: Comparison of model evaluation

Error	**Model**	
	Fuzzy Time Series	**Artificial Neural Network**
MSE	57120876.6463	72748596.88677
RMSE	7557.8354	8529.2788
MAPE	7.1457	9.8528

The comparison shows that the fuzzy time series have the lowest value of MSE, RMSE and MAPE than the artificial neural network model. Therefore, the best model to forecast the monthly export of natural rubber is by using fuzzy time series model because it has the lowest value of MSE, RMSE and MAPE.

CONCLUSION AND RECOMMENDATION

In conclusion, the result by comparing the error measures was employed to choose the best model between the Fuzzy Time Series and Artificial Neural Network. The model that has the smallest error measure value is classify as the best model in forecasting the export of natural rubber. In finding, the Fuzzy Time Series model has the smallest error measures compared to Artificial Neural Network. The value of MSE, RMSE and MAPE of Fuzzy Time Series are 57120876.6463, 7557.8354 and 7.1457 respectively.

There are several recommendations that are suggested for future study. First, researchers also can forecast main export of agricultural commodities in Malaysia by using these two different models. Besides, other models also can be used to make comparisons. From this, it can help to describe the variety of the model selection export of agricultural commodities in Malaysia. Finally, the error measure such as Geometric Root Mean Squared Error (GRMSE) can be applied in comparison and selection of the best model.

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