

IMPROVING FORECAST ACCURACY OF INDONESIAN AGRICULTURAL EXPORTS USING ANFIS SPLITTING RATIOS

Tri Wijayanti Septiarini*¹, Made Diyah Putri Martinasari²

^{1,2} Universitas Terbuka, South Tangerang, Indonesia

*Corresponding Author: tri.wijayanti@ecampus.ut.ac.id

<p>Info Article Received : 14 Juli 2025 Revised : 11 Agustus 2025 Accepted : 23 Agustus 2025 Publication : 30 September 2025</p>	<p>Abstract. <i>Agricultural exports are highly vulnerable to global price volatility and seasonal fluctuations, creating demand for more accurate forecasting methods. This study evaluates the Adaptive Neuro-Fuzzy Inference System (ANFIS) for forecasting Indonesia's monthly agricultural exports, addressing a gap in the literature where soft computing approaches have rarely been systematically applied. Using official trade data from 2012 to 2025, two alternative training-testing schemes (75%:25% and 80%:20%) were implemented with standard preprocessing, and forecasting accuracy was measured using RMSE, MAE, and MAPE. The results show that ANFIS delivered accuracy within widely accepted thresholds under the 75%:25% split, while accuracy declined under the 80%:20% split. Theoretically, the study contributes by clarifying conditions for reliable neuro-fuzzy forecasting and emphasizing standardized evaluation protocols. Practically, the findings provide decision-relevant insights for policymakers and exporters, supporting export target setting, forward-contract planning during volatile price swings, and logistics coordination during peak harvest seasons.</i></p> <p>Abstrak: Ekspor pertanian sangat rentan terhadap fluktuasi harga global dan perubahan musiman, sehingga menimbulkan kebutuhan akan metode peramalan yang lebih akurat. Studi ini mengevaluasi Sistem Inferensi Neuro-Fuzzy Adaptif (ANFIS) untuk meramalkan ekspor pertanian bulanan Indonesia, mengatasi kesenjangan dalam literatur di mana pendekatan komputasi lunak jarang diterapkan secara sistematis. Menggunakan data perdagangan resmi dari tahun 2012 hingga 2025, dua skema pelatihan-pengujian alternatif (75%:25% dan 80%:20%) diterapkan dengan prapemrosesan standar, dan akurasi peramalan diukur menggunakan RMSE, MAE, dan MAPE. Hasil menunjukkan bahwa ANFIS mencapai akurasi dalam batas yang diterima secara luas pada pembagian 75%:25%, sementara akurasi menurun pada pembagian 80%:20%. Secara teoritis, studi ini berkontribusi dengan mengklarifikasi kondisi untuk peramalan neuro-fuzzy yang andal dan menekankan protokol evaluasi standar. Secara praktis, temuan ini memberikan wawasan yang relevan bagi pengambil keputusan dan eksportir, mendukung penetapan target ekspor, perencanaan kontrak berjangka selama fluktuasi harga yang volatil, dan koordinasi logistik selama musim panen puncak.</p>
<p>Keywords: ANFIS, Forecasting, Agricultural Exports, Indonesia, Data Splitting Ratio.</p> <p>Kata Kunci: ANFIS, Peramalan, Ekspor Pertanian, Indonesia, Rasio Data.</p>	
<p>Licensed Under a Creative Commons Attribution 4.0 International License</p> 	

INTRODUCTION

The agricultural sector's productivity, bolstered by public research investments, has historically driven output growth, accounting for 38% of agricultural output from the mid-1970s to mid-2000s (Warr, 2023). However, global price fluctuations and seasonal production cycles exacerbate export volatility, which can be mitigated through market diversification. Studies indicate that diversifying export markets, particularly for processed agricultural products, effectively stabilizes export volatility by enhancing international market share and extending export durations (B. Wang et al., 2023). Furthermore, during the COVID-19 pandemic, agricultural exports remained resilient, positively impacting economic growth, highlighting their importance in times of crisis (Arifah & Kim, 2022). Thus, while agricultural exports are vital, strategic measures are necessary to manage their inherent volatility.

Forecasting methods for agricultural trade have significantly advanced from traditional statistical techniques like ARIMA and exponential smoothing to more sophisticated machine learning (ML) and soft computing approaches that effectively address nonlinearities and uncertainties inherent in agricultural price data. Recent studies demonstrate that ML techniques, such as Generalized Regression Neural Networks (GRNN), Deep Long Short-Term Memory (DLSTM) networks, and hybrid models like CEEMDAN-TDNN, outperform conventional models in terms of predictive accuracy, as evidenced by lower Root Mean Square Error (RMSE) and Mean Absolute Percentage Error (MAPE) values (Pandit et al., 2024). Additionally, reservoir computing methods have shown promise in anticipating price crises by enhancing market direction accuracy, particularly during volatile periods like the COVID-19 pandemic (Domingo et al., 2023). Furthermore, the influence of climatic phenomena such as El Niño and La Niña has been integrated into forecasting models, revealing their potential to improve accuracy over longer horizons (Bonato et al., 2022). This evolution underscores the growing importance of advanced computational techniques in agricultural price forecasting.

In the Indonesian context, existing forecasting studies have predominantly utilized linear or single-method approaches, with limited engagement in advanced soft computing frameworks such as Adaptive Neuro-Fuzzy Inference System (ANFIS). For instance, while traditional models like HBV and NRECA have been employed for hydrological forecasting, hybrid models incorporating ANFIS have demonstrated superior accuracy in streamflow simulation, outperforming conventional methods

significantly (Mohammadi et al., 2021). Moreover, the integration of ANFIS with deep learning techniques has shown remarkable improvements in prediction accuracy for applications like parking occupancy, highlighting the potential of hybrid models in addressing uncertainties and enhancing forecasting precision (Elomiya et al., 2024). Despite these advancements, rigorous evaluation protocols for real-time forecasting conditions remain underexplored, indicating a gap in the application of soft computing methods in Indonesia's forecasting landscape (Rachmawati & Gunawan, 2020). This suggests a need for further research to develop and validate comprehensive hybrid forecasting systems tailored to real-time applications.

Despite advancements in forecasting methodologies, the effectiveness of Adaptive Neuro-Fuzzy Inference System (ANFIS) for modeling Indonesia's agricultural exports remains inadequately documented, particularly under standardized evaluation frameworks that assess both in-sample and out-of-sample performance. ANFIS, which integrates neural networks and fuzzy logic, has shown promise in various applications, including agricultural price forecasting, where hybrid models are increasingly favored for their enhanced predictive capabilities (J. Wang & Zhang, 2020). However, challenges persist in parameter optimization and data scarcity, which can hinder ANFIS performance (Jabeen et al., 2023). Furthermore, while comparative studies highlight the potential of ANFIS and its variants, such as ensemble ANFIS, to achieve high accuracy, they also indicate that these models may struggle with interpretability and sustainability in complex datasets (Tomasiello et al., 2023).

This study aims to evaluate the forecasting performance of ANFIS in predicting Indonesian agricultural exports, guided by the research question of whether soft computing can outperform classical statistical and machine learning benchmarks in terms of accuracy and robustness. Theoretically, this research contributes to the computational forecasting literature by providing a transparent, reproducible application of ANFIS to trade time series, clarifying its strengths and limitations relative to alternative paradigms. Practically, the findings are expected to offer policymakers and exporters reliable forecasting tools to inform export target setting, forward contract planning, and policy design in Indonesia's increasingly dynamic agricultural sector. The paper is organized as follows. Section 2 presents a brief discussion of research method which consist of data used, methods used, and performance evaluation criteria. Section 3 presents result and discussion which is the forecasting results of five. And accuracies

of all models are also discussed. Section 4 contains conclusions and recommendations for the future research.

METHOD

Justification for model selection

The Adaptive Neuro-Fuzzy Inference System (ANFIS) is increasingly popular for its robust forecasting capabilities, particularly in contexts characterized by nonlinearities and uncertainties, such as agricultural exports. ANFIS effectively combines the power of neural networks and fuzzy logic, allowing it to adaptively learn from data while managing inherent uncertainties, which is crucial in volatile agricultural markets (Mohaddes & Fahimifard, 2015). Studies have demonstrated ANFIS's superior performance in various applications, including water distribution systems and environmental modeling, where it outperformed traditional models by significantly reducing prediction errors and improving accuracy (Larrea et al., 2021). Overall, the flexibility and adaptability of ANFIS position it as a compelling choice for forecasting in agricultural contexts, addressing both seasonality and trade shocks effectively. The Adaptive Neuro-Fuzzy Inference System (ANFIS) was selected as the core forecasting model because it combines the learning capability of neural networks with the uncertainty-handling power of fuzzy logic. Compared to linear statistical models or shallow machine learning approaches, ANFIS offers greater flexibility in capturing nonlinearities, seasonality, and uncertain trade shocks, which are common in agricultural export series. Previous studies in other economic contexts have highlighted ANFIS as a strong candidate for small to medium datasets with high volatility, making it particularly suitable for this application.

ANFIS architecture

The ANFIS model constructs a five-layer Takagi–Sugeno fuzzy inference structure as shown in Figure 1. Input variables are fuzzified in the first layer, firing strengths are generated in the second layer, normalized in the third layer, and combined with adaptive linear functions in the fourth layer. The final output is produced in the fifth layer as a weighted sum of all rule outputs. To balance accuracy and interpretability, the number of fuzzy rules was restricted to avoid model over-complexity. The fuzzy inference system was tested with four widely used membership functions: triangular, trapezoidal, generalized bell, and Gaussian. Each function offers

different trade-offs between interpretability and flexibility in capturing nonlinearities. Moreover, in this study, each input variable was assigned gaussian membership functions, yielding a manageable number of rules while preserving nonlinearity capture.

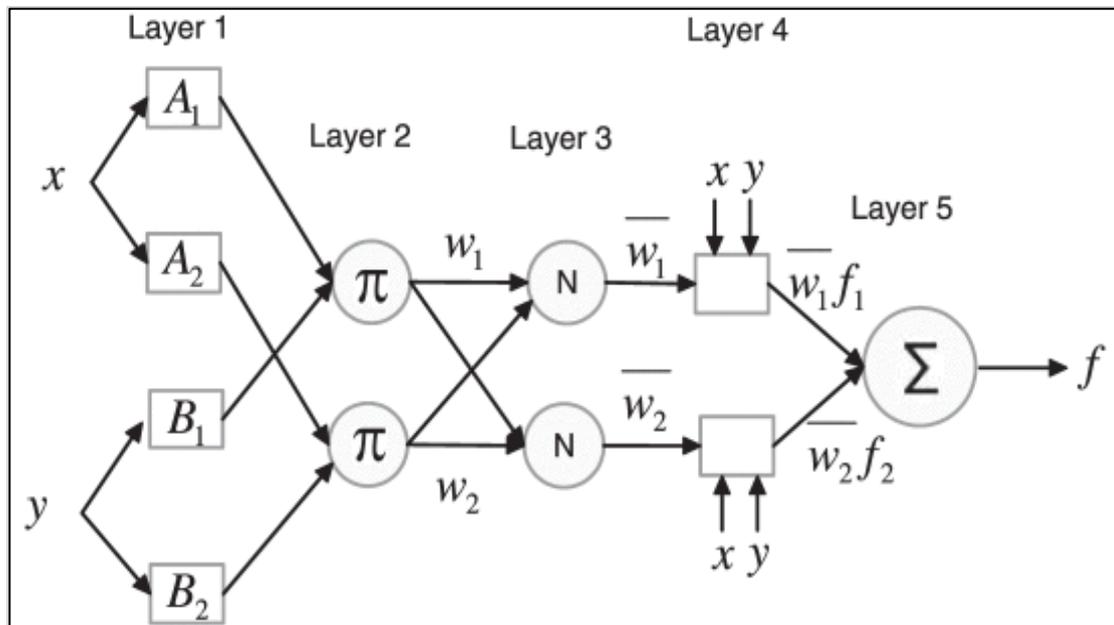


Figure 1. ANFIS Architecture

Learning algorithm and training set up

Training employed the hybrid learning algorithm, combining the least squares estimator (forward pass) for consequent parameters and gradient descent (backward pass) for premise parameters. This approach ensured efficient convergence while minimizing squared prediction errors. Experiments were implemented in Python.

Model validation and overfitting control

To ensure robust evaluation, the data were split into 80%:20% and 75%:25%, training and testing sets (Joseph, 2022; Oghaz et al., 2017; Septiarini et al., 2021). In addition, a distinct splitting data has objective to validate the robustness model.

Evaluation metrics

These measures provide insights into error magnitude, absolute deviation, and relative error proportion, respectively. Comparative analysis across membership functions and training setups was based on these standardized metrics. Forecasting performance was assessed using three complementary metrics:

- 1) Root Mean Square Error (RMSE)

RMSE formula can be described (Erlina & Azhar, 2020) as follow :

$$RMSE = \sqrt{\frac{1}{m} \sum_{i=1}^m (X_i - Y_i)^2}$$

2) Mean Absolute Error (MAE)

MAE formula can be described (Hyndman & Athanasopoulos, 2018) as follow :

$$MAE = \frac{1}{m} \sum_{i=1}^m |X_i - Y_i|$$

3) Mean Absolute Percentage Error (MAPE)

MAPE formula can be described (Phakdi, 2021) as follow :

$$MAPE = \frac{1}{m} \sum_{i=1}^m \left| \frac{X_i - Y_i}{y_i} \right| \times 100\%$$

RESULTS AND DISCUSSION

Descriptive Analysis Data Set

The dataset is Indonesia's agriculture export which expands from January 2012 to May 2025 over 150 months (about 13 years). And the dataset was obtained from <https://satudata.kemendag.go.id/>. Figure 2 depicts the monthly dynamics of Indonesia's agriculture export, representing sharp fluctuations with seasonal patterns and rising trend particularly after month 100. There is a strong, recurring seasonal pattern characterized by regular peaks and troughs within each year. The data shows significant volatility but remains largely contained below 450 units until the final segment. A dramatic surge in export value occurs in the last 20 months, peaking near 650 units, reflecting a major commodity price boom. Overall, the plot indicates increasing export value coupled with high price sensitivity and strong yearly fluctuations.

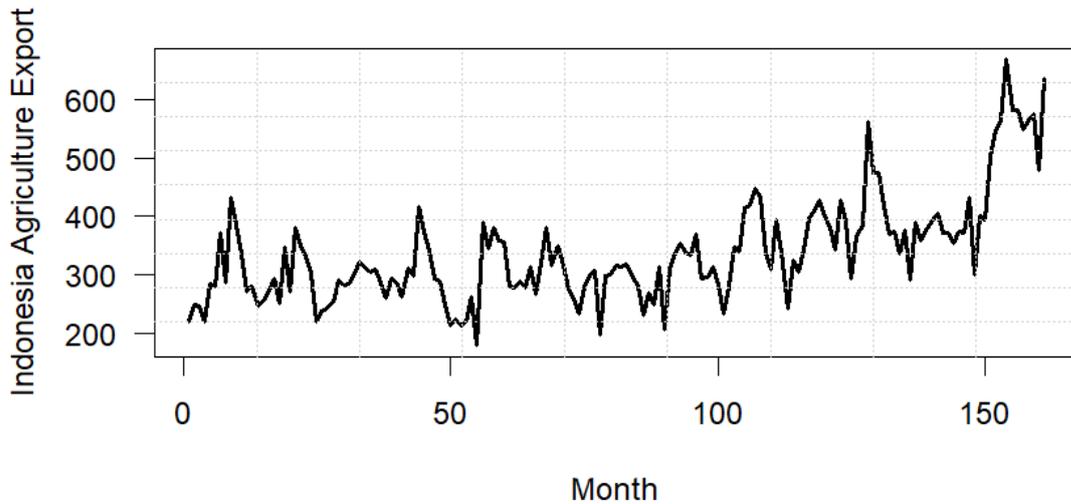


Figure 2 Time Series Plot of Indonesia’s Agriculture Export

Most of dataset’s value are concentrated between 250 and 400, indicating a right-skewed distribution as shown in Figure 3. The most frequent export value, is centered around the 280-300 mark. Furthermore, the occasional export growth is reflected in a smaller proportion of extreme values above 500, supporting to the overall volatility of the dataset. The data exhibits a right-skewed tail and an important gap between 520 and 560, followed by a smaller, separate cluster of high values in the 560-600 range. This suggests that while most export values are moderate, there are a few rare, high-value events or outliers. Overall, the figure highlights the typical range and high variability of the agricultural export data.

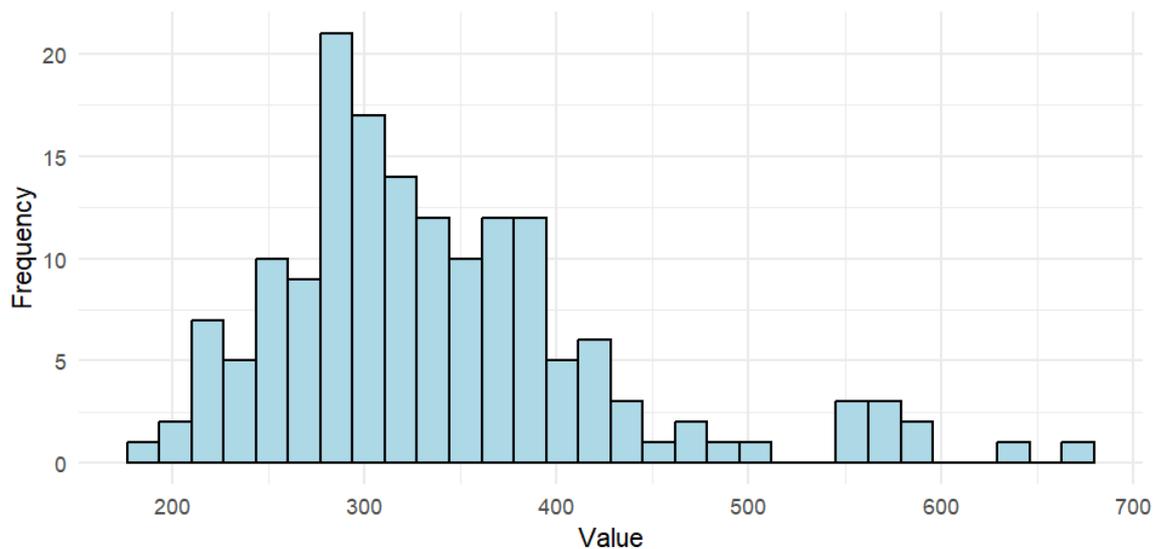


Figure 3 Histogram of Indonesia’s Agriculture Export

Data Splitting Schemes

There are two splitting strategies in this research to evaluate the performance forecasting model which are 75%:25% and 80%:20%, training and testing, respectively as shown in Tabel 1. However, the first splitting dataset provides a larger coverage of volatility during the evaluation steps. This design ensures that the model is trained on sufficiently long historical data while allowing rigorous out-of-sample testing over different horizons.

Tabel 1 Training and Testing Data Partitioning Schemes

Splitting Schemes	Expanding time	
	Training	Testing
75%:25%	January 2012–January 2022	February 2022–May 2025
80%:20%	January 2012–September 2022	October 2022–May 2025

Forecasting Performance under 75:25 Splitting Data

Under 75%:25% splitting data, the ANFIS model obtained high accuracy. In addition, Figure 4 illustrates the forecasting performance of the ANFIS model when trained with 75% of the dataset and validated on the remaining 25%. The forecasted values in red line generally show the overall trend of Indonesia's agricultural export, however deviations from the actual values in blue line are obvious, especially during periods of sharp fluctuations. The predicted series (red line) shows a relatively smoothed trajectory compared to the actual series (blue line), successfully capturing the general level of Indonesia's agricultural export but failing to replicate its sharp fluctuations. The model tends to underestimate peaks and overestimate troughs, which indicates limitations in handling the volatility inherent in agricultural export data. Nevertheless, the closeness of the two curves in several segments suggests that ANFIS is able to approximate the long-term trend reasonably well, even though its short-term responsiveness to sudden changes remains constrained. This highlights the trade-off between trend-following accuracy and volatility representation under the 75:25 data partitioning scheme.

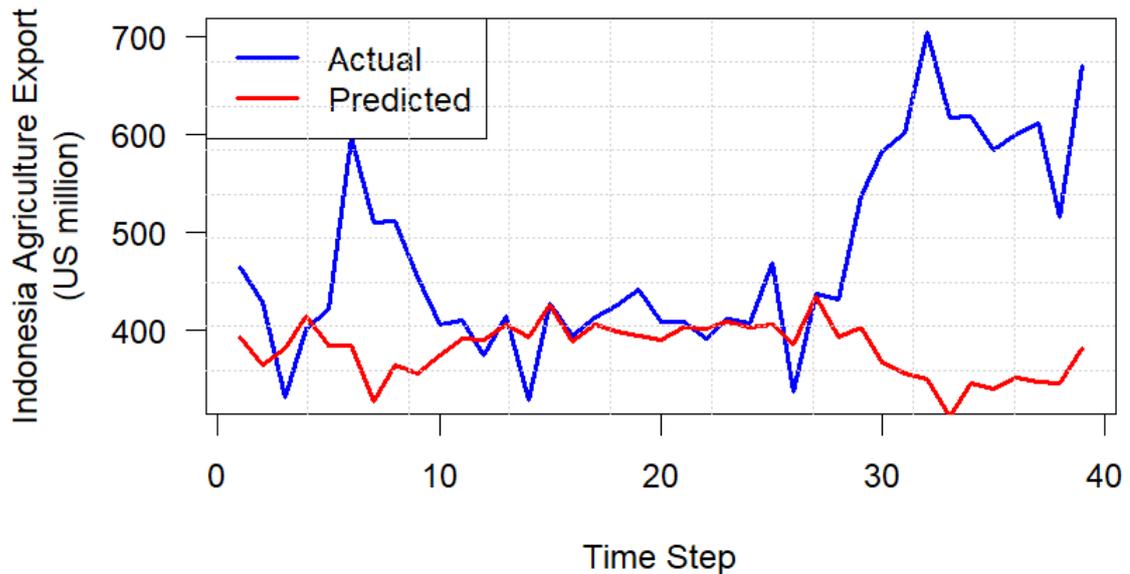


Figure 4 ANFIS Forecasting Results under 75%:25% Data Splitting Scheme

Forecasting Performance under 80:20 Splitting Data

ANFIS performance decreased when the training data enhanced to 80%. Figure 5 presents the ANFIS forecasting results when 80% of the dataset is used for training and 20% for testing. A plot demonstrated that a blue line presents as actual values of Indonesia's agricultural export and the red line shows ANFIS forecasted across sequential time steps. Furthermore, visual analysis indicates that model produces the level and medium-term trend but smooths high-frequency movements. Compared with the 75:25 scheme, the model shows a slightly improved alignment between the predicted (red line) and actual (blue line) values, particularly in capturing the upward shift after the 20th time step. However, the model still exhibits a smoothing effect, underestimating sharp peaks and overestimating troughs, which reduces its ability to fully represent short-term volatility.

The reduced gap between actual and predicted values in several intervals suggests that providing a larger training set improves the model's ability to learn the underlying trend structure. Nonetheless, the persistent deviation during periods of high fluctuation highlights the challenges of ANFIS in modeling abrupt changes in Indonesia's agricultural exports.

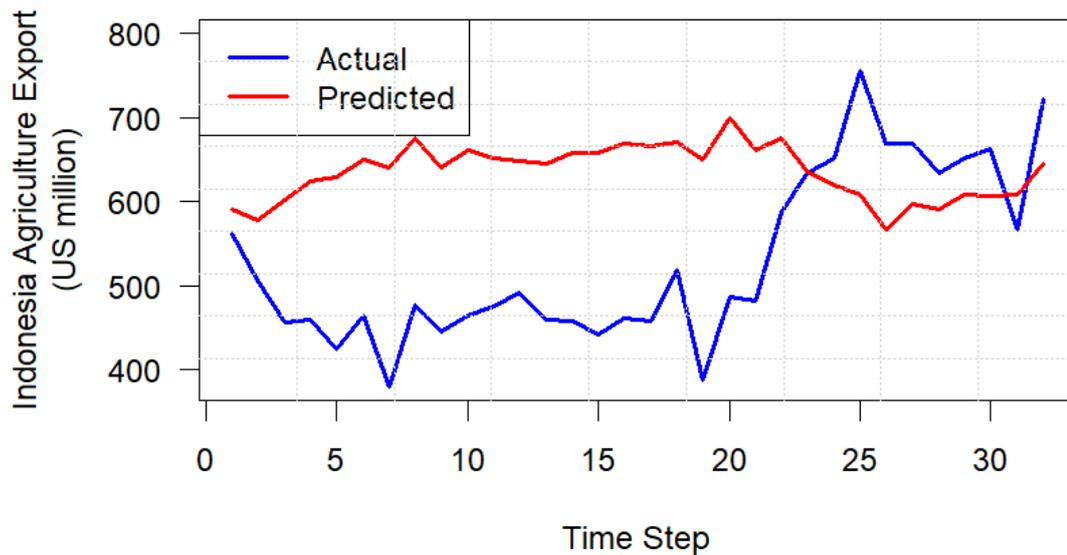


Figure 5 ANFIS Forecasting Results under 80%:20% Data Splitting Scheme

Comparative Interpretation

Table 2 reports the forecasting accuracy of ANFIS under two data splitting schemes, 75%:25% and 80%:20%. The results show that ANFIS achieves acceptable accuracy when using the 75%:25% scheme, as indicated by a Mean Absolute Percentage Error (MAPE) of 18.85%, which is below the widely accepted 20% threshold for reasonable forecast performance (Lewis, 1982). This confirms that the model is able to capture the overall trend of Indonesia's agricultural exports, even though short-term fluctuations are not fully reproduced.

However, when the training proportion is increased to 80%, the forecasting performance deteriorates. The RMSE increases from 148.73 to 158.57, and the MAE rises sharply from 103.68 to 140.75, suggesting that forecast deviations become consistently larger. The most notable degradation occurs in MAPE, which jumps from 18.85% to 29.53%. This implies that forecast errors, relative to the actual export levels, become substantially larger under the 80%:20% scheme.

Interestingly, this result challenges the common expectation that allocating more data to training would improve generalization. Instead, the ANFIS model generalizes poorly when tested on the last 20% of the series. The figures visually confirm this finding: under 80%:20% splitting, the predicted series shows a strong smoothing effect, failing to capture the turning points and sudden changes in export values. In contrast, the 75%:25% scheme produces predictions that track the actual series more closely, particularly around the mid-series fluctuations. Taken together, the analysis suggests that for this dataset, the

75%:25% scheme provides a more reliable balance between learning stability and forecasting accuracy, whereas the 80%:20% scheme leads to overfitting on the training data and weaker generalization in the testing horizon.

Table 2 Forecasting Accuracy of ANFIS Model

Metric	Splitting Schemes	
	75%:25%	80%:20%
RMSE	148.73	158.57
MAE	103.68	140.75
MAPE	18.85%	29.53%

These results are a line with previous research which indicates that soft computing approaches, especially neuro-fuzzy systems, significantly outperform statistical model in forecasting economic and trade time series data. For example, fuzzy cognitive maps (FCMs) integrate fuzzy logic and neural networks, proposing superior adaptability in modeling complex systems and solving non-stationary data set (Orang et al., 2022). In addition, a remarkable forecasting results has been shown by the intuitionistic fuzzy model which obtained up to 80% improvement in performance metrics compared to traditional models (Yolcu & Yolcu, 2022).

Nevertheless, this study is limited by its reliance on aggregate export data, absence of exogenous variables such as exchange rates and global prices, and focus on a single soft computing model without direct benchmarking against classical or machine learning models. Future research should continue the scope by incorporating disaggregated commodity level export, testing combination model such as machine learning, and applying multi-country level comparative frameworks to evaluate external validity.

CONCLUSION

This research evaluates the performance the Adaptive Neuro-Fuzzy System (ANFIS) for forecasting Indonesia's agricultural exports under alternative data partitions. The findings indicate that ANFIS obtained forecasting accuracy within the widely accepted threshold for economics time series data in the 75%:25% splitting scheme, while accuracy decrease in the 80%:20% configuration. These results clarify that partitioning design and rule complexity are crucial parameter of ANFIS performance especially in volatile trade environments. Beyond the empirical insights, this study contributes theoretically by reinforcing the importance of standardized, transparent evaluation

frameworks in soft computing research, and by identifying conditions under which ANFIS can generalize effectively. Practically, the results suggest that neuro-fuzzy forecasts can support policymakers and exporters in setting realistic export targets, optimizing forward contracts during volatile periods, and improving logistics coordination at harvest peaks. Nonetheless, the analysis is constrained by reliance on aggregate export data, omission of exogenous predictors, and a focus on a single model without direct benchmarking. Future research must therefore extend the framework by incorporating.

REFERENCES

- Arifah, K. F., & Kim, J. (2022). THE IMPORTANCE OF AGRICULTURAL EXPORT PERFORMANCE ON THE ECONOMIC GROWTH OF INDONESIA: THE IMPACT OF THE COVID-19 PANDEMIC. *Sustainability (Switzerland)*, 14(24). <https://doi.org/10.3390/su142416534>
- Bonato, M., Cepni, O., Gupta, R., & Pierdzioch, C. (2022). El Niño, La Niña, and FORECASTABILITY OF THE REALIZED VARIANCE OF AGRICULTURAL COMMODITY PRICES: EVIDENCE FROM A MACHINE LEARNING APPROACH. *Journal of Forecasting*, 42(4), 785–801. <https://doi.org/10.1002/for.2914>
- Domingo, L., Grande, M., Borondo, F., & Borondo, J. (2023). ANTICIPATING FOOD PRICE CRISES BY RESERVOIR COMPUTING. *Chaos Solitons & Fractals*, 174, 113854. <https://doi.org/10.1016/j.chaos.2023.113854>
- Elomiya, A., Křupka, J., Jovicic, S. B., & Simić, V. (2024). ENHANCED PREDICTION OF PARKING OCCUPANCY THROUGH FUSION OF ADAPTIVE NEURO-FUZZY INFERENCE SYSTEM AND DEEP LEARNING MODELS. *Engineering Applications of Artificial Intelligence*. <https://doi.org/10.1016/j.engappai.2023.107670>
- Erlina, R. R., & Azhar, R. (2020). FORECASTING MODEL OF AGRICULTURE COMMODITY OF VALUE EXPORT OF COFFEE : APPLICATION OF ARIMA MODEL. 9(3), 257–263.
- Hyndman, R. J., & Athanasopoulos. (2018). FORECASTING: PRINCIPLES AND PRACTICE. OTexts.
- Jabeen, S., Baig, M., & Awais, M. M. (2023). ANFIS LEARNING USING EXPECTATION MAXIMIZATION BASED GAUSSIAN MIXTURE MODEL

- AND MULTILAYER PERCEPTRON LEARNING. *Applied Soft Computing*, 149, 110958. <https://doi.org/10.1016/j.asoc.2023.110958>
- Joseph, V. R. (2022). OPTIMAL RATIO FOR DATA SPLITTING. *STATISTICAL ANALYSIS AND DATA MINING*, 15(4), 531–538. <https://doi.org/10.1002/sam.11583>
- Larrea, P. P., Zapata-Ríos, X., & Parra, L. C. (2021). APPLICATION OF NEURAL NETWORK MODELS AND ANFIS FOR WATER LEVEL FORECASTING OF THE SALVE FACCHA DAM IN THE ANDEAN ZONE IN NORTHERN ECUADOR. *Water*, 13(15), 2011. <https://doi.org/10.3390/W13152011>
- Mohaddes, S. A., & Fahimifard, S. M. (2015). APPLICATION OF ADAPTIVE NEURO-FUZZY INFERENCE SYSTEM (ANFIS) IN FORECASTING AGRICULTURAL PRODUCTS EXPORT REVENUES (CASE OF IRAN ' S AGRICULTURE SECTOR). 17, 1–10.
- Mohammadi, B., Moazenzadeh, R., Christian, K., & Duan, Z. (2021). IMPROVING STREAMFLOW SIMULATION BY COMBINING HYDROLOGICAL PROCESS-DRIVEN AND ARTIFICIAL INTELLIGENCE-BASED MODELS. *Environmental Science and Pollution Research*, 28(46), 65752–65768. <https://doi.org/10.1007/S11356-021-15563-1>
- Oghaz, M. M., Maarof, M. A., Rohani, M. F., Zainal, A., & Mohd Shaid, S. Z. (2017). A HYBRID COLOR SPACE FOR SKIN RECOGNITION FOR REAL-TIME APPLICATIONS. *Journal of Computational and Theoretical Nanoscience*, 14(4). <https://doi.org/10.1166/jctn.2017.6516>
- Orang, O., de Lima e Silva, P. C., & Guimarães, F. G. (2022). TIME SERIES FORECASTING USING FUZZY COGNITIVE MAPS: A SURVEY. *Artificial Intelligence Review*, 56, 7733–7794. <https://doi.org/10.1007/s10462-022-10319-w>
- Pandit, P., Sagar, A., Ghose, B., Paul, M., Kişi, Ö., Vishwakarma, D. K., Mansour, L., & Yadav, K. K. (2024). HYBRID MODELING APPROACHES FOR AGRICULTURAL COMMODITY PRICES USING CEEMDAN AND TIME DELAY NEURAL NETWORKS. *Dental Science Reports*, 14(1). <https://doi.org/10.1038/s41598-024-74503-4>
- Phakdi, P. (2021). FORECASTING MODEL FOR THE VALUE OF ARECA NUT'S EXPORT OF THAILAND. *Webology*, 18(Special Issue), 1241–1253. <https://doi.org/10.14704/WEB/V18SI04/WEB18195>

- Rachmawati, R. R., & Gunawan, E. (2020). PERANAN PETANI MILENIAL MENDUKUNG EKSPOR HASIL PERTANIAN DI INDONESIA. *Forum Penelitian Agro Ekonomi*, 38(1). <https://doi.org/10.21082/fae.v38n1.2020.67-87>
- Septiarini, T. W., Taufik, M. R., & Prasetya, T. A. E. (2021). A COMPARATIVE FORECASTING MODEL OF COVID-19 CASE IN INDONESIA. *Journal of Physics: Conference Series*, 1918(4). <https://doi.org/10.1088/1742-6596/1918/4/042020>
- Tomasiello, S., Uzair, M., Liu, Y., & Loit, E. (2023). DATA-DRIVEN APPROACHES FOR SUSTAINABLE AGRI-FOOD: COPING WITH SUSTAINABILITY AND INTERPRETABILITY. *Journal of Ambient Intelligence and Humanized Computing*, 14, 16867–16878. <https://doi.org/10.1007/s12652-023-04702-w>
- Wang, B., Liu, X., Chi, M., & Li, Y. (2023). BAYESIAN NETWORK BASED PROBABILISTIC WEIGHTED HIGH-ORDER FUZZY TIME SERIES FORECASTING. *Expert Systems With Applications*. <https://doi.org/10.1016/j.eswa.2023.121430>
- Wang, J., & Zhang, W. (2020). FUZZY MATHEMATICS AND MACHINE LEARNING ALGORITHMS APPLICATION IN EDUCATIONAL QUALITY EVALUATION MODEL. *Journal of Intelligent & Fuzzy Systems*, 39(4), 5583–5593.
- Warr, P. (2023). PRODUCTIVITY IN INDONESIAN AGRICULTURE: IMPACTS OF DOMESTIC AND INTERNATIONAL RESEARCH. *Journal of Agricultural Economics*. <https://doi.org/10.1111/1477-9552.12533>
- Yolcu, O. C., & Yolcu, U. (2022). A NOVEL INTUITIONISTIC FUZZY TIME SERIES PREDICTION MODEL WITH CASCADED STRUCTURE FOR FINANCIAL TIME SERIES. *Expert Systems with Applications*, 215, 119336. <https://doi.org/10.1016/j.eswa.2022.119336>