

Predicting Fishermen's Income Based on Weather Factors and Fishing Location Using the Neuro-Fuzzy Algorithm

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Abstract : Fishermen's income is influenced by weather conditions, fishing locations, and vessel characteristics, making it difficult to predict consistently. This study aims to predict fishermen's income using the Adaptive Neuro-Fuzzy Inference System (ANFIS) based on boat load, boat width, rainfall, and fishing location. The study employed an applied quantitative approach using data from small-scale fishermen in the Belawan area. The research stages included preprocessing, fuzzification, fuzzy rule formation, training, testing, and evaluation using MAE and RMSE. The results show that ANFIS can generate income predictions based on the selected variables. In one test observation, the model predicted approximately IDR 1,000,000, compared with an actual value of IDR 1,249,572, resulting in an error of IDR 249,572. The prediction results can also be presented through a dashboard as supporting information for fishing activity planning. These findings indicate that ANFIS has potential as a method for supporting fishermen's income prediction.

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Introduction

Fishermen's income is the income received by fishing households after fishing for a certain period of time and is used to meet various household needs, such as basic necessities, electricity bills, provision of fishing facilities and infrastructure, fishing expenses, and children's education costs. Fishermen's income tends to be unstable because the results obtained can vary from one period to another. This condition also causes fishermen's ability to meet daily consumption needs to change. When the income earned is higher, household needs can be more easily met, whereas when the results earned are lower, meeting daily needs can be limited (Lukum et al., 2023). This condition indicates that fishermen's income is closely related to the catch obtained from fishing activities.

Catch instability is also related to changing aquatic environmental conditions. Changing weather conditions can impact fishing activities because fishermen still rely on experience and knowledge inherited from generation to generation to determine fishing times and locations. Sea surface conditions

are one factor influencing pelagic fish that live in the surface layers and water column, while wind also needs to be considered because wind speed can affect wave height. Sari and Wiyono (2022) showed that weather changes are related to seasonal patterns of pelagic fishing, making weather conditions a crucial aspect to consider in fishing activities. In addition to weather conditions, fishing locations can also influence the number of fish caught because each water area has different environmental conditions and fish resource availability.

Indonesia has significant potential for fishery resources due to its geographical location as an archipelagic nation. This potential should have a positive impact on coastal communities, particularly those working as fishermen. Fishery resources can potentially be utilized to improve the standard of living and welfare of fishermen. However, conditions in the field indicate that many fishermen still face economic hardship because their catches have not been able to increase optimally, resulting in a decline in income (Ahmad Ridha, 2020). Fishermen's income is also influenced by the time they spend at sea. The more time fishermen have available and use for fishing activities, the greater the potential income they will earn (Konoralma, 2020).

Another problem faced by fishermen is changing weather, which causes uncertainty in determining the appropriate time and conditions for going to sea. Changes in the physical state of the atmosphere that occur over time can impact the activities of communities dependent on natural resources, including fishermen. Increasingly unpredictable seasonal conditions, strong winds that can occur at any time, heavy rainfall outside the season, and the emergence of large waves can increase uncertainty in fishing activities. These conditions require fishermen to be more cautious in deciding to go to sea because changing weather can affect catches and risks during fishing activities (Maurizka Intan Shafa & Adiwibowo Soeryo, 2021). Therefore, weather factors such as wind speed, seawater temperature, wave height, and rainfall need to be considered when estimating fishermen's catch and income.

Besides weather, fishing location and vessel characteristics are also factors related to fishermen's catches. Fishing areas have different water conditions, which can produce different types and quantities of catch. Determining fishing areas can take into account water conditions, security, fishing area, and weather conditions (Larasati et al., 2024). Furthermore, vessel capacity or load is related to the ability to transport the catch and can be a factor related to fishermen's income. These various factors indicate that fishermen's income is not solely influenced by a single condition, but is also related to changes in weather, fishing location, and vessel characteristics. Traditional data processing is insufficient to describe the more complex relationships between these factors. Therefore, an approach is needed that can process data under uncertain conditions and with non-simple relationships. Predictions are also needed to estimate possible conditions based on available information to minimize errors between estimates and actual conditions (Yohanni Syahra, 2022).

Based on these conditions, this study aims to predict fishermen's income based on weather factors, fishing location, and vessel characteristics using the Neuro-Fuzzy algorithm or Adaptive Neuro-Fuzzy Inference System (ANFIS). This method combines artificial neural networks and fuzzy logic so that it can be used to process data that has uncertainty and complex relationships (Fatkhurrozi et al., 2012). The application of this method is expected to produce income predictions based on the conditions faced by fishermen and become supporting information in determining the time and location of fishing. The urgency of this research lies in the need to obtain predictive information that is more appropriate to weather conditions, fishing location, and vessel characteristics to assist fishermen in planning fishing activities. The novelty of this study lies in the use of the Neuro-Fuzzy algorithm to predict fishermen's income by considering weather factors and fishing location simultaneously and including vessel characteristics as part of the variables used in the prediction process.

Method

The study, entitled "Predicting Fishermen's Income Based on Weather Factors and Fishing Location Using the Neuro-Fuzzy Algorithm," is a quantitative study with an applied research type. The study uses a computational and experimental approach by applying the Adaptive Neuro-Fuzzy Inference System (ANFIS) algorithm to predict fishermen's income based on weather factors, fishing location, and vessel characteristics. The model is built through data processing, training, and testing stages, then the predicted results are compared with actual data. The use of Neuro-Fuzzy is based on its ability to combine artificial neural networks and fuzzy logic in processing data that has uncertainty

(Fatkhurrozi et al., 2012).

The research instruments consist of hardware and software used to process data and build predictive models. The hardware used is a laptop with 4 GB RAM and 64 GB SSD storage. The software used is Python with the NumPy and Pandas libraries for data processing, Scikit-Fuzzy for fuzzy logic, ANFIS or custom ANFIS for Neuro-Fuzzy modeling, and Matplotlib and Scikit-Learn for model visualization and evaluation. Data analysis techniques are carried out through data processing, ANFIS model formation, training, testing, and evaluation using RMSE and MAE values.

The research population consisted of data on fishing activities and income of small-scale fishermen operating in the Belawan area. The research sample consisted of data containing information on weather conditions, fishing locations, vessel characteristics, and fishermen's income. The weather data used included wind speed, seawater temperature, wave height, and rainfall, while vessel characteristic data included cargo and width. Data lacking information necessary for the prediction process were not used in the study.

The research procedure was carried out through several stages, namely collecting data on weather, fishing locations, vessel characteristics, and fishermen's income, followed by processing and preparing the data as model input. The data was then used in the formation and training of the Neuro-Fuzzy model through the stages of fuzzification, fuzzy rule formation, inference, normalization, and defuzzification. The trained model was then tested using test data and the predicted results were compared with actual data using RMSE and MAE. The final result was a prediction of fishermen's income based on weather conditions, fishing locations, and vessel characteristics.

Results and Discussion

Dataset Description

The dataset used in this study was obtained in the form of a Microsoft Excel file containing data on fishermen in the study area. The data was collected to represent various factors that influence fishermen's income, particularly those related to weather conditions, vessel characteristics, and fishing locations. Each data item describes the actual conditions of fishermen with varying values, allowing it to be used to build a representative predictive model.

Overall, the dataset consists of several attributes, namely fisherman's name, age, watershed name, boat load, boat width, rainfall, fishing location, and fisherman's income. However, not all attributes are used in the modeling process. Attributes such as fisherman's name and watershed name are not used because they do not directly influence the prediction. Therefore, the variables used as input in this study include boat load, boat width, rainfall, and fishing location, while the output variable is fisherman's income.

Based on observations of the dataset, it appears that ship load, vessel width, and rainfall vary significantly. This variation indicates differences in fishermen's operational conditions and environmental conditions that influence catches. Fishermen's income, as an output variable, also shows varying values, reflecting the influence of these factors. With this data variation, the Neuro-Fuzzy model is expected to optimally learn the relationship between input and output variables.

Data Preprocessing

Before the modeling process is carried out, the data first undergoes preprocessing to ensure its quality. The initial stage is data selection, which involves selecting attributes relevant to the research objectives. The attributes used include ship load, vessel width, rainfall, fishing location, and fishermen's income.

Next, data transformation was performed, particularly for the categorical fishing location variable. This variable was converted into numeric form so it could be processed by the system. Afterward, data normalization was performed to equalize the scales between variables, thus optimizing the model training process. The final stage was dividing the dataset into training and testing data. The training data was used to train the model to recognize patterns of relationships between input and output variables, while the testing data was used to test the model's ability to predict new data.

Implementation of Neuro-Fuzzy Method

The method used in this research is the Adaptive Neuro-Fuzzy Inference System (ANFIS), which combines fuzzy logic and artificial neural networks. This method is used to predict fishermen's income based on predetermined input variables. The initial stage involves fuzzification, which converts numerical data into linguistic values using Gaussian membership functions.

As an example, manual calculations used data from the dataset: a ship's cargo of 33.72 tons, a ship width of 8.28 meters, rainfall of 206.55 mm, and a sea location of Belawan, coded as 1, with actual revenue of 1,249,572 rupiah. The calculation steps are as follows:

1. Fuzzification

$$\mu(x) = e^{-(x - c)^2 / 2\sigma^2}$$

a. Ship Cargo

$$c = 25.36$$

$$\sigma = 5.21$$

By Calculation

$$(33.72 - 25.36) = 8.36, 8.36^2 = 69.862 \times (5.21^2) = 2 \times 27.14 = 54.28$$

$$\mu = \exp(-69.86 / 54.28) \mu = \exp(-1.287) \mu \approx 0.276$$

b. Rainfall

$$c = 200$$

$$\sigma = 50$$

$$(206.55 - 200) = 6.55, 6.55^2 = 42.902 \times 50^2 = 5000$$

$$\mu = \exp(-42.90 / 5000) \mu = \exp(-0.00858) \mu \approx 0.991$$

c. Ship Width

$$c = 7$$

$$\sigma = 2$$

$$(8.28 - 7) = 1.28, 1.28^2 = 1.642 \times 2^2 = 8$$

$$\mu = \exp(-1.64 / 8) \mu = \exp(-0.205) \mu \approx 0.815$$

d. Location

$$\text{Belawan} = 1 \rightarrow \mu = 1$$

2. Fire Strength

$$w = \mu_1 \times \mu_2 \times \mu_3 \times \mu_4$$

$$w = 0.276 \times 0.991 \times 0.815 \times 1 = 0.273 \times 0.815 = 0.222$$

3. Calculate Output

$$f_i = p_i x_1 + q_i x_2 + r_i x_3 + s_i x_4 + t_i$$

$$x_1 = 33.72$$

$$x_2 = 8.28$$

$$x_3 = 206.55$$

$$x_4 = 1$$

Parameters (training results): $p = 100000$

$$q = 50000$$

$$r = -2000$$

$$s = 100000$$

$$t = 1000000$$

$$\text{Count : } 100000 \times 33.72 = 3,372,000$$

$$50000 \times 8.28 = 414,000 - 2000 \times 206.55 = -413.100100000 \times 1 = 100,000$$

$$\text{Total: } f = 4,472,000$$

4. Defuzzification

$$Y = w^- \times f$$

$$Y = 0.222 \times 4,472,900 Y \approx 993,000$$

4.3.5. Comparison with Actual Value

$$\text{Prediction} \approx 1,000,000$$

$$\text{Actual} = 1,249,572$$

$$\text{Error:} = 1,249,572 - 1,000,000 = 249,572$$

Prediction Results

After implementing the Neuro-Fuzzy Logistics (ANFIS) method, the next step is to test the model to obtain predictions of fishermen's income. The testing process uses test data taken from the dataset, where each data point is tested against the model developed in the previous stage.

The prediction results are obtained through a series of stages: fuzzification, fuzzy rule formation, rule strength calculation, weight normalization, and defuzzification, which produces a final value in the form of a revenue prediction. Each input data item, including ship load, ship width, rainfall, and fishing location, is processed by the system to produce a predicted value, which is then compared with the actual value.

The predictions obtained from the model do not always approximate the actual values, as they are influenced by several dynamic and complex factors. Variables such as high rainfall, ship load capacity, vessel width, and water location significantly influence fishermen's income. Changes in these factors can cause significant differences between predicted and actual values. Therefore, although the Neuro-Fuzzy model is able to capture the relationship between variables, there is still a possibility of significant differences in predictions due to actual conditions in the field that cannot be fully modeled.

Furthermore, the prediction results are then displayed in a system dashboard to make it easier for users to read and understand the resulting information. The dashboard is designed interactively, displaying input data, prediction results, and a comparison between predicted and actual values. This interface allows users to easily view analysis results without having to understand complex calculation processes.

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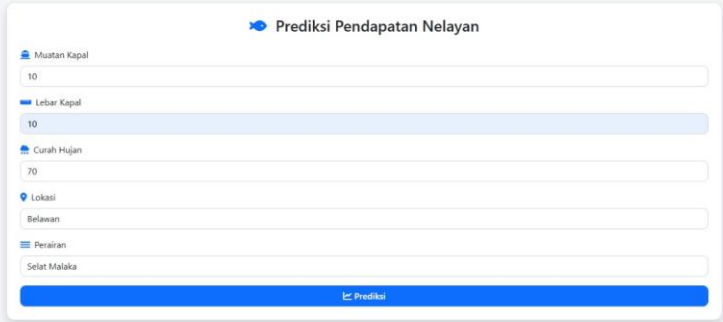
The screenshot displays a web-based prediction system titled "Prediksi Pendapatan Nelayan". It features a vertical list of input fields on the left side, each with a corresponding icon: a ship for "Muatan Kapal" (value 10), a ruler for "Lebar Kapal" (value 10), a cloud with rain for "Curah Hujan" (value 70), a location pin for "Lokasi" (value "Belawan"), a fishing boat for "Penairan" (value "Selat Malaka"), and a document icon for "Prediksi". A large blue button labeled "Prediksi" is positioned at the bottom right of the input area.

Figure 1. Main View

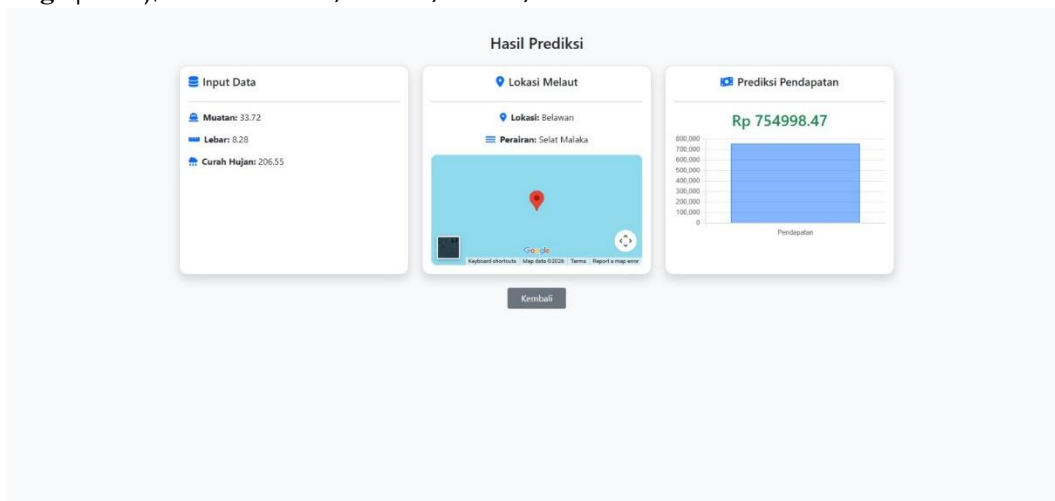


Figure 2. Prediction Results

Model Evaluation

The MAE and RMSE calculations in this study were performed in stages by first calculating the error for each data item. Each predicted value was compared with the actual value to obtain the difference (error) for each item. This approach aims to provide a clearer picture of the model's error level for each item before calculating the overall average. For example, one item used had an actual value of IDR 1,249,572 and a predicted value of IDR 1,000,000. The resulting error difference is calculated as follows:

$$\text{Error} = |\text{Actual} - \text{Prediction}| = |1,249,572 - 1,000,000| = 249,572$$

The error value is then used in the MAE and RMSE calculations. The MAE calculation is carried out using the formula:

$$MAE = \frac{1}{n} \sum_{i=1}^N |y_i - \hat{y}_i|$$

Since the example only uses one data, then:

$$\begin{aligned} MAE &= 249,572 / 1 \\ &= 249,572 \end{aligned}$$

Next, the RMSE calculation is carried out using the formula:

$$RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^N (y_i - \hat{y}_i)^2}$$

The first step is to square the error value:

$$(249,572)^2 = 62,286,178,784$$

Then divided by the number of data:

$$62,286,178,784 / 1 = 62,286,178,784$$

Next, the root is: $RMSE = \sqrt{62,286,178,784} = 249,572$

The calculation results show that the MAE and RMSE values are the same, at 249,572. This occurs because the calculation was performed on only one data point, so there was no averaging process across multiple data points. However, in this study, the MAE and RMSE calculations were performed on all data in the dataset, so the final value obtained is the average of all existing errors. Thus, the evaluation results can provide a more accurate picture of the model's performance in predicting fishermen's income.

In addition, this manual calculation is carried out to show the evaluation process in detail, while the overall calculation is carried out using a system to obtain faster and more accurate results.

Results Analysis

Based on the results of the testing and evaluation, it can be analyzed that the Neuro-Fuzzy (ANFIS) method is capable of predicting fishermen's income with a fairly good level of accuracy. This

is evident in the predictions, which tend to be close to the actual values, although some data still show significant differences.

The difference between predicted and actual values is influenced by several dynamic factors, such as weather conditions, particularly rainfall, which can fluctuate unpredictably. Furthermore, vessel load and width also contribute to fishermen's catches, with larger vessels tending to generate higher returns. Fishing location is also a crucial factor, as each water area has varying catch potential.

The analysis also shows that the Neuro-Fuzzy model is capable of capturing nonlinear relationships between input and output variables. This is an advantage over conventional methods, as ANFIS combines the flexible fuzzy logic approach with the learning capabilities of artificial neural networks. This allows the model to adapt to complex data patterns.

However, the model still has several limitations. The resulting error values for some data indicate that the model is not fully able to represent real-world conditions. This could be due to limited data volume, high data variation, and other factors not yet incorporated into the model, such as wind conditions, ocean waves, and fishermen's experience.

Furthermore, the parameters used in the model significantly influence the prediction results. If the parameters obtained from the training process are not optimal, the resulting predictions will also be suboptimal. Therefore, a better parameter optimization process is needed to ensure the model produces more accurate predictions.

The analysis concluded that the Neuro-Fuzzy Method (ANFIS) was quite effective in predicting fishermen's income, but further development is needed to improve accuracy. This could be achieved by increasing the data volume, improving data quality, and adding other variables relevant to field conditions.

Discussion

The research results show that vessel load, vessel width, rainfall, and fishing location influence fishermen's income. Vessel load and width are related to fishermen's capacity and operational ability to catch fish, while rainfall and fishing location are related to environmental conditions that affect catches. The combination of these variables produces specific patterns that can be studied by the ANFIS model to generate predictions.

However, during testing, it was discovered that the predicted results did not always align closely with the actual values. This was due to several factors, such as unpredictable weather conditions, differences in catch potential at each location, and other external factors not included in the model. Furthermore, limited data and suboptimal parameter optimization can also impact model accuracy.

In terms of implementation, the developed system is capable of displaying prediction results in a dashboard, making it easier for users to understand the resulting information. The dashboard displays input data, prediction results, and comparisons with actual values, making it a useful decision-making tool. With an interactive and informative interface, users don't need to understand complex calculations to obtain prediction results.

Overall, the Neuro-Fuzzy (ANFIS) method has advantages in handling uncertain data and nonlinear relationships between variables. However, to improve model performance, further development is needed, such as increasing the data volume, optimizing parameters, and adding other variables more relevant to field conditions. With these developments, the model is expected to provide more accurate predictions and be more optimally utilized to assist fishermen in making decisions before going to sea.

Conclusion

This study shows that the Adaptive Neuro-Fuzzy Inference System (ANFIS) algorithm can be applied to predict fishermen's income based on ship load, ship width, rainfall, and fishing location variables. The prediction process is carried out through the stages of preprocessing, fuzzification, fuzzy rule formation, fire strength calculation, normalization, and defuzzification. The implementation results on sample data with a ship load of 33.72 tons, a ship width of 8.28 meters, rainfall of 206.55 mm, and a fishing location of Belawan produce a predicted value of around Rp1,000,000 with an actual value of Rp1,249,572 and a difference of Rp249,572. These results indicate that the model is able to learn the relationship between input variables and fishermen's income and produce predicted values that can be

compared with actual conditions. The system has also been able to present the predicted results through a dashboard so that the information can be understood more easily.

The limitations of this study lie in the quantity and variety of data and the failure to include all factors that can influence fishermen's income, such as wind conditions, wave height, and fishermen's experience. Furthermore, model parameter optimization still needs to be improved, as it can affect prediction results. Future research is recommended to use a larger and more diverse dataset, improve preprocessing quality, optimize ANFIS parameters, and consider other variables relevant to fishing conditions. Practically, the developed prediction system can provide supporting information for fishermen in considering weather conditions, fishing locations, and vessel characteristics before engaging in fishing activities. The available dashboard can also help users obtain prediction information without having to directly understand the ANFIS calculation process.

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