JURNAL TEKNISI **E-ISSN: 2775-0965**
(Jurnal Teknologi Komputer dan Sistem Informasi)
Agustus 2024, Vol 4, No 2, Hlm. 48 – 57
Available online at http://jurnal.goretanpena.com/index.php/teknisi

PERFORMANCE ANALYSIS OF REGRESSION MODEL IN MACHINE LEARNING TO PREDICTION RICE PRICES

Muhammad Ardiansyah Sembiring[1], Diana Lestari[1*] ,Maysaroh Rambe[1]
[1]Information System, Universitas Royal
Email:*dianalestarii21@gmail.com

Abstract: The trade sector has become increasingly unpredictable, often experiencing drastic fluctuations in commodity prices, especially essential goods like rice. Rice plays a crucial role in people's livelihoods, and rising prices can significantly reduce purchasing power for other necessities. This study aims to predict wholesale rice prices using independent variables such as Dry Paddy Price, Paddy Field Area, Fuel Price, Perton Production, and Cooking Oil Price. Seven regression estimation methods were applied: (1) Linear Regression, (2) Support Vector Regression Linear, (3) Support Vector Regression RBF, (4) Decision Tree Regression, (5) Random Forest Regressor, (6) Gradient Boosting Regression, and (7) MLP Regressor. The objective is to determine the method with the best accuracy for deployment in rice price prediction. The results show that Decision Tree Regression outperformed other methods, achieving the highest accuracy of 90% at a 90:10 data ratio, 80% at 80:20, 70% at 70:30, and 60% at 60:40. It also produced the lowest error values (MSE = 0.00000000, RMSE = 0.00000000) and the highest R^2 score (1.00000000), confirming its superior predictive performance for estimating rice prices.

Keywords: decision tree regression; machine learning; price estimation; rice price prediction.

Abstrak: Sektor perdagangan saat ini semakin tidak stabil, sering mengalami fluktuasi harga komoditas yang signifikan, terutama pada kebutuhan pokok seperti beras. Beras menjadi faktor penting dalam kehidupan masyarakat karena kenaikan harganya dapat menurunkan daya beli terhadap kebutuhan lain. Penelitian ini bertujuan memprediksi harga beras grosir dengan variabel independen yaitu Harga Gabah Kering, Luas Lahan Sawah, Harga Bahan Bakar, Produksi Perton, dan Harga Minyak Goreng. Tujuh metode regresi digunakan: (1) Linear Regression, (2) Support Vector Regression Linear, (3) Support Vector Regression RBF, (4) Decision Tree Regression, (5) Random Forest Regressor, (6) Gradient Boosting Regression, dan (7) MLP Regressor. Tujuannya adalah menentukan metode dengan akurasi terbaik untuk diterapkan dalam prediksi harga beras. Hasil menunjukkan bahwa Decision Tree Regression merupakan metode terbaik dengan akurasi tertinggi 90% pada rasio data 90:10, 80% pada 80:20, 70% pada 70:30, dan 60% pada 60:40. Metode ini menghasilkan nilai error terendah (MSE = 0.00000000, RMSE = 0.00000000) serta nilai R^2 tertinggi (1.00000000), menunjukkan kinerja prediksi terbaik dalam estimasi harga beras.

Kata Kunci: decision tree regression; estimasi harga; pembelajaran mesin; prediksi harga beras.

JURNAL TEKNISI **E-ISSN: 2775-0965**
(Jurnal Teknologi Komputer dan Sistem Informasi)
Agustus 2024, Vol 4, No 2, Hlm. 48 – 57
Available online at http://jurnal.goretanpena.com/index.php/teknisi

INTRODUCTION

In today's era of globalization, information technology is developing rapidly. This technology has a significant impact on various aspects of human life. It also makes it easier to solve various problems, including trade. The trade sector is currently highly unpredictable, sometimes experiencing significant price increases or decreases. This, in turn, leads to increased public boredom. This is especially true when these price increases involve essential commodities. One example of a staple food that is highly sought after by Indonesians is rice. Rice is a staple food in every country. This makes it a crucial factor in people's livelihoods. Rising rice prices can reduce people's purchasing power for other necessities. According to detailed data from the Indonesian Central Statistics Agency (BPS), the average wholesale price of rice in November 2022 was Rp 11,012/kg, a 0.6% increase compared to Rp 10,947/kg the previous month. Compared to the same period last year, it represents a 6.14% increase. Therefore, information technology is crucial in this regard. With the right information technology and methods, it is hoped that this can be a solution to address uncertainty regarding rice price estimates for the following month or year. Most methods used by agencies, wholesalers, and small traders still predict rice prices using relatively simple and ineffective methods. These methods typically rely on guessing rice prices based solely on experience, but also on predictions from several months prior. These methods don't take into account other factors that might influence price increases or decreases, making them less effective for predicting rice prices. The same method is still used at the State Logistics Agency (Bulog) in Asahan Regency. They predict rice prices by looking at prices from several months prior. This results in minimal efficiency in their rice price predictions, and it's also difficult to predict rice prices in the event of certain situations and conditions that could influence, or even significantly impact, price increases or decreases. One of BULOG's primary responsibilities is to maintain stable food prices in the market by intervening in supply and demand. Given this responsibility, BULOG should employ more effective and efficient methods than those previously employed.

Therefore, an information system capable of predicting rice prices based on certain influencing factors is urgently needed. This information system would facilitate Perum BULOG in handling one of its responsibilities more effectively. One method that can be used in this information system is regression. The regression method is a statistical analysis method used to see the relationship between two or more variables. The relationship is functional and presented in mathematical form. Essentially, the regression method is a statistical analysis technique that aims to calculate the causal relationship between two or more different variables. Regression is used to determine the properties and strength of the relationship between two variables and to predict the value of an unknown variable based on past observations of that variable and other variables [1] . By creating a web-based system or application for predicting rice price increases, the public in Indonesia will have wide access to utilize the research results later.

METHOD

This research method contains information related to the research implementation and the steps to be taken to achieve the desired results. This research method includes:

Research Equipment

In this research, equipment such as a computer with appropriate specifications, Jupyter notebook software in Anaconda Navigator which uses the Python programming language, Visual Studio Code

JURNAL TEKNISI **E-ISSN: 2775-0965**
(Jurnal Teknologi Komputer dan Sistem Informasi)
Agustus 2024, Vol 4, No 2, Hlm. 48 – 57
Available online at http://jurnal.goretanpena.com/index.php/teknisi

as a text editor and HTML as a markup language will be used to create application deployments.

Variables Contained in Research

In the context of machine learning, this research is classified as supervised learning research which is a modeling method where the data used has a label/target/class. The purpose of this method is to determine the causal relationship between the independent variable and the variable that is the target/label. The variables used in this study include the Price of Dry Paddy (Rp/Kg), Rice Production (Ton), Fuel Price (Liter/Rp) and Land Area (Hectare), as well as the dependent variable, namely the Price of Rice (Rp/Kg).

Research Stages

The stages to be taken in this research are described in a flowchart so that the stages to be carried out can be clearly seen.

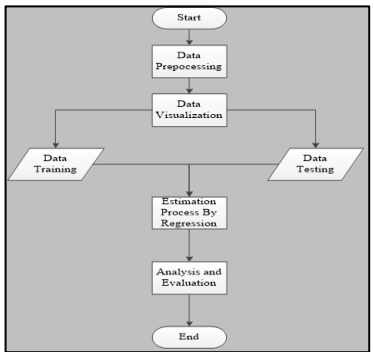

Image 1. Flowchart of Estimation System Stages

Image 1 depicted that the first stage to be carried out is Data Preprocessing where in the process there is data cleaning to handle missing data, data selection to select data based on the columns to be studied and data transformation. The second stage is to perform data visualization, namely to present a representation of the distribution of the data used. The next stage is to separate the data set into 2 parts, namely training data and testing data. After that, enter the estimation process stage using regression which includes 7 regression models and test the data with testing data. Then the final stage is the data analysis and evaluation stage using 4 evaluation methods, namely MAE, MSE, RMSE and R2-Score, the goal is to obtain accurate results from the estimation process so that the best method with the best evaluation results is obtained.

Research Data

The research data used is a rice price dataset taken from BPS from 2019-2022. The total data is 97 rows. There are 5 columns (dry grain price, rice field area, fuel price, production per ton, cooking oil price) that will be used for testing and 1 column (Rice Price at Wholesale) as the label/target. The sample dataset that will be described in this study uses the top 5 data as contained in Table (1), namely:

Table 1. Sample Dataset

Price of Dry Paddy	Rice Field Area	Fuel Prices	Production Per Ton	Cooking Oil Prices	Rice Prices at Wholesalers
9433.17	4494.67	433043.00	8500.00	2514020.00	13700.00
9531.20	4501.84	433043.00	8500.00	2519020.00	13700.00
9595.89	4210.54	433043.00	8500.00	2529020.00	13700.00
9424.65	4010.54	433043.00	8500.00	2517020.00	13700.00
9413.91	4209.36	433043.00	8500.00	2519020.00	13700.00

JURNAL TEKNISI **E-ISSN: 2775-0965**
(Jurnal Teknologi Komputer dan Sistem Informasi)
Agustus 2024, Vol 4, No 2, Hlm. 48 – 57
Available online at http://jurnal.goretanpena.com/index.php/teknisi

Split Data

In this study, data sharing was performed using training data and testing data with a ratio of 90:10. Training data covers 90% of the dataset and testing data covers 10% of the dataset. The algorithm that uses this ratio has better performance compared to other algorithms with an accuracy rate of 99.40% [2] . In addition, data sharing ratios such as 80:20, 70:30 and 60:40 were also used in this study to obtain a regression model that has the best estimation results.

Estimation with 7 Regression Models

Regression is the most commonly used method to analyze the influence between variable x (the independent variable) and variable y (the dependent variable). In the estimation process, seven regression models were used to compare the best model. The seven regression models used include:

Linear Regression

Linear regression is divided into two types: simple linear regression and multiple linear regression . According to research, simple linear regression is a model that analyzes the relationship between one predictor variable and one response variable. The study also stated that predictions using simple linear regression yielded good results, demonstrating the best prediction results during January 2021 [3] . The equation for simple linear regression is as follows:

$$Y = a + bx \quad (1)$$

Information:
Y : Dependent variable
a : the point where the line intersects the y coordinate
b : coefficient of independent variable
x : independent variable

Then, multiple linear regression or multiple linear regression according to [5]is an analysis model that describes the relationship between the response variable (Y) and the variables that influence it (x) where the variable (x) is more than one. The equation used in multiple regression is:

$$Y = b0 + b1X1 + b2X2 + b3X3 + \dots + bnXn$$

Information :
Y : response variable
X: predictor variable that influences the response variable
b0 : intercept
b : coefficient

Support Vector Regression – Linear

It is a regression model used to correct overfitting and has a good accuracy value [5] . Overfitting is a condition where the data when processed/ trained approaches the almost perfect predicted results [4] . The equation contained in the support vector regression model is as follows:

$$f(x) = w^t(p(x) + b$$

Information :
f(x) : regression function
W^t : weight vector which has dimension l
(p(x) : point in space F, the result of mapping x to the input space
b : is a bias

Support Vector Regression – RBF (Radial Basis Function)

The equations contained in support vector regression with the Gaussian-RBF kernel function are:

$$K(x_{i,}x) = \exp(-\frac{1}{2a^2}\|x - x_i^T\|^2) \quad (2)$$

Decision Tree Regression

decision tree regression equation first looks for the entrophy value as in the following equation:

$$\text{entro}(S) = \sum_{i=1}^{m} -p(w_i|S \,.\, \log_2(w_i|S)$$

Information :
S = Case Set
M = Total data classes
($w_i | S$) = Proportion of the ith class *in* all training data processed at node S.
[5].

JURNAL TEKNISI **E-ISSN: 2775-0965**
(Jurnal Teknologi Komputer dan Sistem Informasi)
Agustus 2024, Vol 4, No 2, Hlm. 48 – 57
Available online at http://jurnal.goretanpena.com/index.php/teknisi

Then, after obtaining the entrophy value, we then look for the gain value as follows:

$$Gain(S,J)=Entropy(S)-\sum_{i=j}^{n} p(v_i|S)*E(S_i)$$

Information :
S : Case set
J : Features
n : Number of classes in *node* (root)
($v_i \mid S$) : Proportion of values v appearing in the class in *the node* (root)
(S_i) : Entropy of the composition of the v values of the jth class in the i-th data node

Random Forest Regressor

According to research [6] Random forest is a regression algorithm that combines predictions from multiple machine learning solutions to achieve better accuracy than a single model. The study also concluded that random forest regression is more accurate than linear regression , with an accuracy rating of 97.7% using RMSE and MAPE calculations. The random forest regressor equation is shown below:

$$\hat{\gamma}_i = \frac{1}{N_{tree}} \sum_{n=1}^{N_{tree}} \hat{\gamma}_n$$

Information :
$\hat{\gamma}_i$: prediction results
N_{tree}: total number of trees
$\hat{\gamma}_n$: prediction result of the nth tree

Gradient Boosting Regression

It is part of an ensemble algorithm that uses accuracy enhancement to improve a value. The gradient boosting regression model is capable of handling complex patterns. The data structure of gradient boosting regression is a decision tree . The gradient boosting regression equation is as follows:

$$r_{im} = -\left[\frac{\partial L(y_i,F(x_i))}{\partial F(x_i)}\right]_{F(x)=F_{m-1}(x)} \text{ for } i=1,\ldots, n$$

Natural Language Processing (NLP) Regressors

It is the ability of a computer program to process human language, both spoken and written, with the aim of designing or building an application that is used to facilitate human communication with machines through natural human language.

Accuracy Measurement Model Using Error Values

The data that has been processed using 7 regression models is then measured for accuracy. Data processing that is estimated in nature and still contains an element of uncertainty, it is necessary to include an error value as a measure of the accuracy of the estimate. The error value is the difference between the actual observed value and the predicted value. For estimates measured using MAE, MSE, and RMSE, the best value is the smallest value, the smaller the resulting value means the better the estimation result. In contrast to the R2-Score, the value of the determinant coefficient that is close to 1 means that the independent variable provides all the information needed to estimate the dependent variable [11]. The error value that will be used is 4 models of measuring the accuracy of the estimated value, including:

RESULTS AND DISCUSSION

The discussion in this study will be conducted through data visualization to facilitate observation and to determine the relationship between each x-variable and the y-variable. Furthermore, the data will be tested using four different data distribution ratios, with seven regression models and four evaluation value models. This aims to determine which regression model best produces the most accurate value for use in rice price increases. The discussion steps are as follows:

JURNAL TEKNISI **E-ISSN: 2775-0965**
(Jurnal Teknologi Komputer dan Sistem Informasi)
Agustus 2024, Vol 4, No 2, Hlm. 48 – 57
Available online at http://jurnal.goretanpena.com/index.php/teknisi

Data Visualization

Data visualization aims to make it easier for someone to observe and understand data. There are various models that can be used to present data in visual form. *Scatter* plots use the "matplotlib.pyplot" *library* . In this study, data visualization uses *scatter* plots, which aim to view the distribution of data and observe the extent of the influence between the x-axis and the y-axis.

Scatter Plot of Dry Paddy Prices Against Wholesale Rice Prices

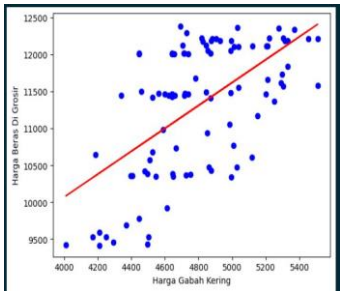

Image 2. Scatter of Dry Paddy Prices Against Wholesale Rice Prices

In the image above, the dot plot of the distribution of rice prices at wholesalers (y-axis) is visualized by the blue dots. Based on the image, it can be seen that the higher the price of dry grain, the higher the price of rice. This relationship is unidirectional because the increase in the x-axis is followed by an increase in the y-axis.

***Scatter* Plot of Rice Field Area and Rice Prices at Wholesalers**

Next, the data visualization display shows the area of rice fields (x-axis) against the price of rice (y-axis).

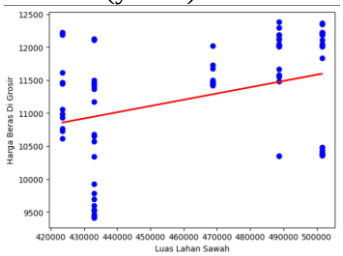

Image 3. The Scatter of Rice Field Area on Rice Prices at Wholesalers

Data visualization in the scatterplot of the x-axis (Rice Field Area) against the y-axis (Wholesale Rice Price) is shown in Figure 3. It shows a direct relationship between the two variables. This is indicated by the intercept line that slopes slightly upward, although the relationship is not very significant.

***Scatter* Plot Of Fuel Prices Against Rice Prices At Wholesalers**

The following is a visualization of data from fuel prices (x-axis) to wholesale rice prices (y-axis).

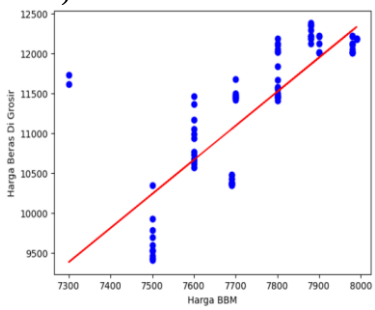

Image 4. Scatter of Fuel Prices against Rice Prices at Wholesalers

The data visualization shows that fuel prices significantly influence wholesale rice prices. This is evident from the line indicating that the two variables influence each other.

***Scatter* Plot of Cooking Oil Prices Against Rice Prices at Wholesalers**

Below is a picture of the distribution of data from variable x (Price of Cooking Oil) to variable y (Price of Rice at Wholesalers).

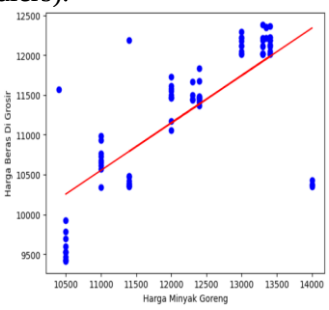

Image 5. Scatter of Cooking Oil Prices Against Rice Prices at Wholesalers

JURNAL TEKNISI **E-ISSN: 2775-0965**
(Jurnal Teknologi Komputer dan Sistem Informasi)
Agustus 2024, Vol 4, No 2, Hlm. 48 – 57
Available online at http://jurnal.goretanpena.com/index.php/teknisi

The data distribution visualized above shows the relationship between cooking oil prices and wholesale rice prices. The data demonstrates a positive relationship, as the line shows that the increase in cooking oil prices is directly proportional to the increase in rice prices.

Data Testing with 7 Regression Models

This study uses a regression method where a comparison of 7 regression methods will be conducted to obtain a model with the best accuracy results for use in the process of increasing rice prices. This study uses data division to be tested as many as 5 forms, including the first ratio division of 90:10, the second 80:20, the third 70:30 and the fourth ratio of 60:40 . Data testing with varying ratios to find and determine which regression model appears most frequently in producing the best estimated value. Thus, the best regression model will be known in estimating the dataset to find the increase in rice prices. The following is a discussion of the research to find the best regression model which is described in detail in the following points:

Accuracy Testing on 90:10 Data Ratio

The first data test used a 90:10 ratio, where the training data was 90% of the total data and the testing data was 10% using 7 regression models. The results were as shown in the table below:

Table 2. Accuracy on Ratio 90:10

MODEL	MAE	MSE	RMSE	R2-SCORE
Linear Regression	2.57097342	8.09162808	2.84457872	8.76741175
SVR-Linear	5.75362895	5.70303422	7.55184363	-8.68735538
SVR-RBF	6.53672758	6.70439866	8.18803924	-2.12732118
DecisionTree	0.00000000	0.00000000	0.00000000	1.00000000
RandomForest	2.83946667	1.71765903	4.14446501	9.97961519
GradientBoosting	1.95821820	6.09467351	2.46873925	9.99276697
MLP-Regressor	9.25379084	9.22604168	9.60522862	-1.09482694

In viewing the estimation results, the rule used is to use the smallest measurement values of MAE, MSE, and RMSE as indicators of good estimation results. Meanwhile, for R2-Score, the value closest to 1 and far from 0 indicates the best estimate. Based on the table, the Decision Tree Regressor method produces the best estimate value on the best measurement model among all existing methods. Based on this analysis, the Decision Tree Regressor method is obtained as the best regression method at a data ratio of 90:10 because it obtains the best estimate value on 4 measurement models, namely MSE, RMSE, and R2-Score.

Accuracy Testing on 80:20 Data Ratio

second data test uses a ratio of 80:20 , where *the training data* is 80 % of the total data and *the testing data* is 20 % using 7 regression models , the results are as shown in the table below:

JURNAL TEKNISI **E-ISSN: 2775-0965**
(Jurnal Teknologi Komputer dan Sistem Informasi)
Agustus 2024, Vol 4, No 2, Hlm. 48 – 57
Available online at http://jurnal.goretanpena.com/index.php/teknisi

Table 3. Accuracy on Ratio 80:20

MODEL	MAE	MSE	RMSE	R2-SCORE
Linear Regression	2.16944988	1.07379982	3.27688849	8.48640493
SVR-Linear	3.24875394	1.37526335	3.70845432	-1.93851876
SVR-RBF	7.10848208	7.13386877	8.44622328	-5.56812088
DecisionTree	0.00000000	0.00000000	0.00000000	1.00000000
RandomForest	3.07801857	2.92292682	1.75442827	9.97961519
GradientBoosting	1.95821820	6.09467351	1.70965693	9.99587993
MLP-Regressor	9.25379084	9.22604168	9.60522862	-1.09482694

In this test, the Decision Tree Regressor method was found to be the best regression method among the seven other methods. This is evident from the Decision Tree Regressor's best estimate value across the three measurement models. The Decision Tree Regressor method was the best method in the test, with a ratio of 80:20 because its estimated result was 1. Therefore, this method was the best in the test, with an accuracy of 80:20.

Accuracy Testing on 70:30 Data Ratio

second data test uses a ratio of 70:30 , where the training data is 70 % of the total data and the testing data is 30 % using 7 regression models , the results are as shown in the table below:

Table 4. Accuracy on Ratio 70:30

MODEL	MAE	MSE	RMSE	R2-SCORE
Linear Regression	5.32009248	3.97633510	6.30581882	4.64209317
SVR-Linear	5.55608873	4.78066883	6.91423809	-6.44169512
SVR-RBF	6.54412376	7.53998427	8.68330828	-1.59746202
DecisionTree	0.00000000	0.00000000	0.00000000	1.00000000
RandomForest	6.81670000	2.69172031	1.6406431	9.97961519
GradientBoosting	3.02796248	1.38585567	3.7227082	9.98123631
MLP-Regressor	1.80799560	4.09946923	2.02471460	-5.51382373

In this test, the Decision Tree Regressor method was found to be the best regression method out of the seven other methods. This can be seen from the best estimation value of the Decision Tree Regressor in the three measurement models. The *Decision Tree Regressor method* was the best method in the test with a ratio of 7.0 : 3.0 because the estimated result was 1. Therefore, this method is

considered the best method in the test with an accuracy of 7.0 : 3.0

.

Accuracy Testing on 60:40 Data Ratio

second data test used a ratio of 60:40 , where *the training data* was 60 % of the total data and *the testing data* was 40 % using 7 regression models , the results were as shown in the table below:

Table 5. Accuracy on Ratio 60:40

MODEL	MAE	MSE	RMSE	R2-SCORE
Linear Regression	4.77820065	3.09962932	5.56743147	5.53415413
SVR-Linear	4.98589259	5.04809256	7.10499301	2.49553466
SVR-RBF	7.21266244	7.03352728	8.38645174	-1.33290081
DecisionTree	0.00000000	0.00000000	0.00000000	1.00000000
RandomForest	8.81392727	2.98367919	1.72733297	9.99102734
GradientBoosting	1.92599802	6.22769324	2.49553466	1.16351405
MLP-Regressor	1.4900487	2.67368464	1.63514056	-3.84215853

Based on the table above, it can be confirmed that the Decision Tree Regressor method is the best method in the 60:40 test and is also the method that appears most frequently among the other estimated values. Decision Tree Regressor produces 0 for the MAE measurement, 0 for the MSE, 0 for the RMSE, and 1 for the R2-Score. Therefore, in testing data with a 60:40 ratio, the best method is Decision Tree Regressor.

Comparison Of The 3 Best Regression Methods

After testing the accuracy of four data ratios, the best method was found, producing the highest estimated values. This method was decision tree regression. Decision tree regression was the best method, with high accuracy rates , including ratios of 90:10 , 80:20, 70:30, and 60:40, with an accuracy rate of 100% .

CONCLUSION

The trade sector's volatility, particularly in essential commodities like rice, significantly impacts people's purchasing power, making rice price prediction crucial. This study developed a rice price prediction model using seven regression methods—Linear Regression, SVR Linear, SVR RBF, Decision Tree, Random Forest, Gradient Boosting, and MLP Regressor—based on independent variables such as Dry Paddy Price, Paddy Field Area, Fuel Price, Perton Production, and Cooking Oil Price, with Wholesale Rice Price as the dependent variable. Using Jupyter Notebook, Visual Studio Code, and Python, model performance was tested at four data ratios (90:10, 80:20, 70:30, and 60:40). The Decision Tree Regression method consistently produced the best results, achieving accuracy levels of 90%, 80%, 70%, and 60% respectively, with MSE, RMSE, and MAE values of 0.00000000 and an R^2 score of 1.00000000. Therefore, Decision Tree Regression was

identified as the most accurate and reliable method for predicting rice prices and will be used in future deployment for rice price forecasting in Asahan Regency.

BIBLIOGRAPHY

[1] V. Tulus Pangapoi Sidabutar, Study of electric vehicle development in Indonesia: prospects and obstacles, J. Paradig. Ekon., vol. 15, no. 1, pp. 2138, 2020, doi: 10.22437/paradigm a.v15i1.9217.

[2] T. Abdullah and R. Boedisantoso, Calculation of Green Open Space Based on Carbon Dioxide Emissions, J. Pijar Mipa, vol. 14, no. 1, pp. 9599, 2019, doi: 10.29303/jpm.v14i1.997.

[3] E. Alfisyahri, N., Karimi, S. and Ridwan, Causal Relationship between Hydropower Energy Consumption, Carbon Dioxide Emissions and Economic Growth in G20 Countries, J. Ilm. MEA (Management, Econ. Accounting), vol. 4, no. 1, pp. 114127, 2020.

[4] FD Permatasari, S. Hadisusanto, and E. Haryono, CO2 Emissions of Motor Vehicles During the Large-Scale Social Restriction Policy Period (Case Study: Road Sections in Central Jakarta), Ecolab, vol. 15, no. 1, pp. 3144, 2021, doi: 10.20886/jklh.2021.15.1.31-44.

[5] Central Statistics Agency. https://www.bps.go.id/indicator/17/57/1/jumlah-kendaraan-motor.html (accessed May 19, 2022).

[6] Bappeda of the Special Region of Yogyakarta. http://bappeda.jogjaprov.go.id/artikel/detail/46-a-pollusi-udara-dan-uji-emisi-gas-buang-kendaraan-bermotor-sebagai-prasyarat-pemberian-perpanjgn-stnk (accessed May 19, 2022).

[7] Carbon Emissions from Indonesian Forest Fires Reach 41.4 Million Tons in 2021 | Databoks. https://databoks.katadata.co.id/datapublish/2022/01/11/emisi-karbon-dari-kebakaran-hutan-i ndonesia-capai-414-juta-ton-pada-2021 (accessed May 21, 2022).

[8] Transportation Contributes 27% of Energy Sector Emissions | Databoks. https://databoks.katadata.co.id/datapublish/2021/03/03/transportasi-sumbang-sepertiga-emisi-sektor-energi (accessed May 21, 2022).

[9] A. Kurnia and Sudarti, Greenhouse Effect, J. Educator. Phys. and Science, vol. 4, no. 2, pp. 19, 2021.

[10] B. Leu, The Impact of Global Warming and Efforts to Control It Through Environmental Education and Islamic Education, At-Tadbir, vol. 1, no. 2, pp. 115 , 2021, doi: 10.51700/attadbir.v1i2.207.