JOIV : Int. J. Inform. Visualization, 9(2) - March 2025 831-837

INTERNATIONAL JOURNAL
ON INFORMATICS VISUALIZATION

journal homepage : www.joiv.org/index.php/joiv

Recommendation System for Mobile-Based Oil Palm Fertilization Period with Rainfall Prediction using ANN

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Abstract*— Weather conditions significantly affect human activities, including the oil palm plantation sector, which in practice considers weather and climate conditions. Oil palm is an annual crop that requires proper nutrition throughout the year. Plant nutrition through fertilization must be according to the specific needs of oil palms. Knowing the type of fertilizer, calculating the dosage, and evaluating the climatic characteristics significantly affect the effectiveness and efficiency of fertilization. According to one palm oil farmer, fertilization should ideally be done when the soil is moist or not during the dry season so plants can absorb fertilizers properly. If fertilization is ineffective, then the operational costs of plant maintenance to buy fertilizers become less efficient. Due to climate change, farmers often find it difficult to determine the optimal timing of fertilization. Therefore, rainfall prediction is essential. Thus, fertilization can run well and get maximum results. The recommendation system in this research includes a rainfall prediction system with machine learning methods and an Artificial Neural Network. The recommendation system is a mobile-based application that allows oil palm farmers to obtain information on the appropriate time to fertilize based on rainfall. The evaluation of rainfall prediction using ANN has the MSE value of 0.0019981 and the MAPE value of 9.355%. It can be concluded that the rainfall prediction model is working optimally. This system can be combined with harvesting forecasting and recommendations of oil palm plantation periods to become a monitoring system for oil palm productivity.

***Keywords*— Rainfall prediction; neural network; fertilization; oil palm.**

Manuscript received 7 Jul. 2024; revised 10 Sep. 2024; accepted 5 Mar. 2025. Date of publication 31 Mar. 2025.

I. INTRODUCTION

Oil palm is the largest vegetable oil-producing tropical crop in the world. The global demand for vegetable oil continues to increase along with population growth [1], [2]. The oil palm plantations area in 2022 is estimated to reach 15.38 million hectares spread across 26 provinces in Indonesia. According to the status of the plantation, the oil palm plantation is grouped into smallholder plantations (PR), large state plantations (PBN), and large private plantations (PBS) [3], [4]. Of the three, PBS controlled around 54.69%, PR reached 41.44%, and PBN was only around 3.88% of the total oil palm plantation area in Indonesia in 2020. Moreover, the percentage of production in 2020 was 61.07% by PBS, 33.88% by PR, and 5.05% produced by PBN. Riau is the largest oil palm grower in Indonesia, with an area of 2.86 million hectares and production of 8.86 million tons in 2020 [5]. To optimize the productivity and sustainability of oil palm, a plantation management system needs to be developed to monitor various activities that support oil palm productivity [6], [7].

Fertilization is a part of oil palm plantation management along with other activities such as land clearing, nursery, planting, maintenance, crop protection, and harvesting operations [8]. From the beginning of the nursery until the production of oil palms that are approximately 20 years old, fertilization is an essential activity because it dramatically affects the vegetative growth and productivity of oil palm fresh fruit bunches (FFB) [9], [10]. Two types of nutrients need to be considered: macronutrients and micronutrients. These nutrients are assumed to be available in the soil, but the nutrient content will decrease over time. Low nutrient availability in the soil can cause plants to show nutrient deficiency symptoms. Improper cultivation and non-intensive planting lead to a decrease in the amount of nutrients in the soil. Increasing the nutrient content can be done with fertilization [10], [11].

The production and profitability of oil palm cultivation can be increased by paying attention to Fertilization effectiveness and efficiency. The fertilization cost can range from 40-60% of total crop maintenance costs or about 24% of total production costs. Failure to fertilize can reduce the production and profitability of oil palm cultivation [10], [12], [13]. Fertilization also depends on the climate, which determines the timing of fertilizer application [12], [14] Climate is commonly defined as the weather averaged over a long period. The weather is the state of the air at a specific time and place that is relatively narrow for a short period. One of the weather parameters that is often used as a reference for weather prediction is rainfall. Rainfall is the amount of water that falls on the area within a given time measured in millimeters above the horizontal surface when no evaporation, runoff, or infiltration occurs [15]. The change in rainfall patterns can shift between the wet and dry seasons.

The optimum fertilization is conducted when rainfall is around 150-250 mm/month, a minimum of 60 mm/month, and a maximum of 300 mm/month [16]. However, if there is a drought with less than 60 mm/month of rainfall, fertilization should be passed, and fertilization can be carried out again when 50 mm/10 days of rain have fallen. Additionally, fertilization cannot be carried out if rainfall is more than 30 mm/day and rainy days are 20 days/month because conditions are too wet, which can result in water-saturated soil [1], [17].

So, how do we know when rainfall is appropriate for optimum fertilization? Meteorology and Geophysics Agency in Riau Province has rainfall data for each month in a year. This data can be used to predict which month of rainfall is appropriate for optimum fertilization using the machine learning method. Therefore, rainfall prediction in the Recommendation System for Mobile-Based Oil Palm Fertilization Period is needed. The rainfall prediction in this application uses machine learning methods, such as artificial neural networks [18], [19], [20].

Previous researchers have conducted several studies on fertilization recommendation systems and rainfall prediction systems using Artificial Neural Networks. Firmansyah and Putra [21] have produced an oil palm fertilization dose application that can provide fertilization recommendations for five types of macronutrients (N, P, K, Ca, and Mg). Furthermore, Cahyati [22] has developed a system for converting rainfall prediction data into a planting calendar using Backpropagation. The results of the prediction of rainfall data for Deli Serdang Regency, Medan in 2020 from January to December are obtained from the training and testing process using the backpropagation algorithm. Research conducted by Agrawal [23] stated that the ANN algorithm is the most suitable for predicting rainfall data. The fast process of connecting learning data and output data leads to ANN having a higher correction speed by utilizing the concept of the correlation coefficient. Nordin [24] stated that ANN is an algorithm that can predict and recognize patterns by continuously learning to minimize errors, repeatedly cycling, and stopping when the error value reaches the goal or has reached the maximum epoch. This study using Melaka rainfall data from 2019 to 2021. Thakur et al. [25] do a literature review report about rainfall prediction using different techniques on ANN algorithms such as Back Propagation, ARIMA, ANN, K-NN, ABFNN, Hybrid Wavelet-NARX model, Wavelet-ANN, Rainfall-runoff models, Multilayer perceptron. And the accuracy was found to be more than 95%. Based on that review, Thakur believes that the rainfall prediction that used ANN techniques was much superior to numerical weather prediction (NWP) and statistical methods. Shukla [26] uses ANN for rainfall prediction and compares it with LSTM. The result is that the RMSE values of LSTM during training epochs indicate a tendency for the training dataset to overfit.

This research aims to build a Recommendation System for a Mobile-Based Oil Palm Fertilization Period with rainfall prediction using Artificial Neural Network. The FerSys is the name of that application. The research results are a recommendation application for fertilization time based on rainfall prediction, the dose needed, the amount of fertilizer required, and a recording of the fertilization history. The FerSys can assist oil palm farmers in determining the right fertilization time. This can have an impact on the productivity of palm oil heads. Moreover, oil palm farmers can also regularly see the recommended dosage and record fertilization time.

II. Materials and Method

The development of a Recommendation System for Mobile-based Oil Palm Fertilization Period, FerSys, goes through several steps. A literature study researches references to other sources in previous studies related to this final project. It helps in understanding the working mechanism used in this research. The next step is user requirements to identify palm oil farmers' need for the system, which will be built through interviews and field surveys. The next step is the design of rainfall prediction using a machine learning method and a design that describes the system in general description. The design uses documentation such as system architecture, case diagrams, scenarios, ANN flowcharts, system interface design, and ANN manual calculations for recommendation mobile-based applications. For rainfall prediction using machine learning, there are several steps, which are data acquisition, data preprocessing, modeling, and model evaluation [27]. Then, the implementation process where machine learning modeling is implemented with the ANN method using the Python programming language and coding for mobile applications using the Flutter framework. Then, after the implementation step, the next step is testing the compatibility of the system built with the system design. After that, testing the machine learning model is also carried out to assess the accuracy of the prediction results.

A. *Design of Rainfall Prediction Using ANN*

The system begins data acquisition using rainfall data from 2008-2022 for Ujung Batu, the location of the plantation where the research was conducted. The Data was obtained from the Riau BMKG Climatology Station through in-person and online interviews and was subsequently used for data preprocessing. To improve the quality of data, imputation is applied. Data imputation can be performed by filling in the meaning of the available data. For example, if there are many missing values in January, the missing data can be replaced using the average of January data from 2008 to 2022. Besides using the *Mean*, imputation can also be done using the data's median or middle value. However, using mean and *Median* is only effective if the proportion of missing values is less than 10%. If missing values exceed 10%, data interpolation methods can fill in the missing values. There are several types of interpolation methods, one of which is linear interpolation.

The imputation process used the linear interpolation, mean, and median methods because the data contained too many blanks. Fig. 1 shows a graph of cleaned data. The next step is modeling machine learning with the Artificial Neural Network method using 12 input layers, 600 hidden layers, and 12 output layers. Each input layer (Xn, i = 1, 2, 3, ..., n) receives input Xi and forwards it to all hidden layers Z1, ..., Zp. Each hidden layer calculates its activation using the weight values. The formula using Eq (1)

$$Znet\ ij = (\sum_{ij=1}^{n} \text{wij} * \text{xij}) + \text{bij} \quad (1)$$

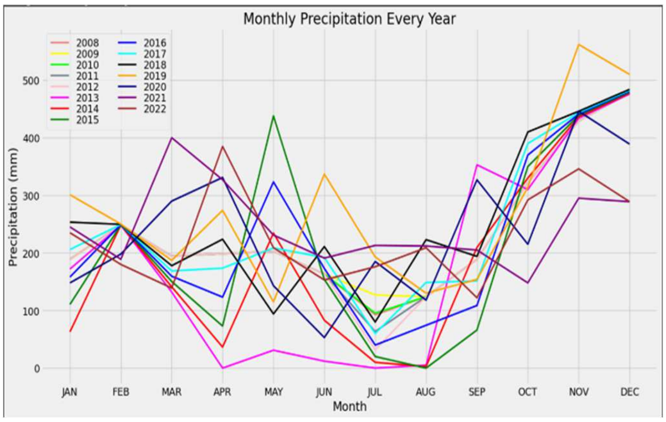

Fig. 1 Monthly Precipitation Every Year

Calculate the δ factor of each output unit Ojk (jk = 1, 2, 3, ..., n). And calculate the δ factor of each output unit Zij (ij = 1, 2, 3, ..., n). The formula using Eq (2)

$$\delta in\ 1 = \sum_{i=1}^{12} \delta_1 W_{1,1} \quad (2)$$

Calculating the new weight value and correcting the bias value using the formula in Eq (3)

$$\Delta v1{,}1 = \alpha \delta 1 x1 \quad (3)$$

Sum the weight value and bias value, then update it. Repeated each step up to the predetermined epoch limit. Fig. 2 shows the flow of ANN modeling. After modeling, the next step is evaluating the machine learning model by calculating the MSE and MAPE values shown in Table I. MSE and MAPE are calculated using formulas Eq (4) and Eq (5). Additionally, the accuracy and loss of training and validation data were compared. Fig. 3 shows the comparison results of accuracy training and validation. Fig. 4 shows the comparison results of loss training and loss validation.

$$MSE = \sum \frac{(y' - y)^2}{n} \quad (4)$$

$$MAPE = \frac{1}{n} \sum \frac{|\hat{y}_t - y_t|}{y_t} x100 \quad (5)$$

TABLE I
MODEL EVALUATION

Metrics	Result
MSE	0.0019981
MAPE	9.355%

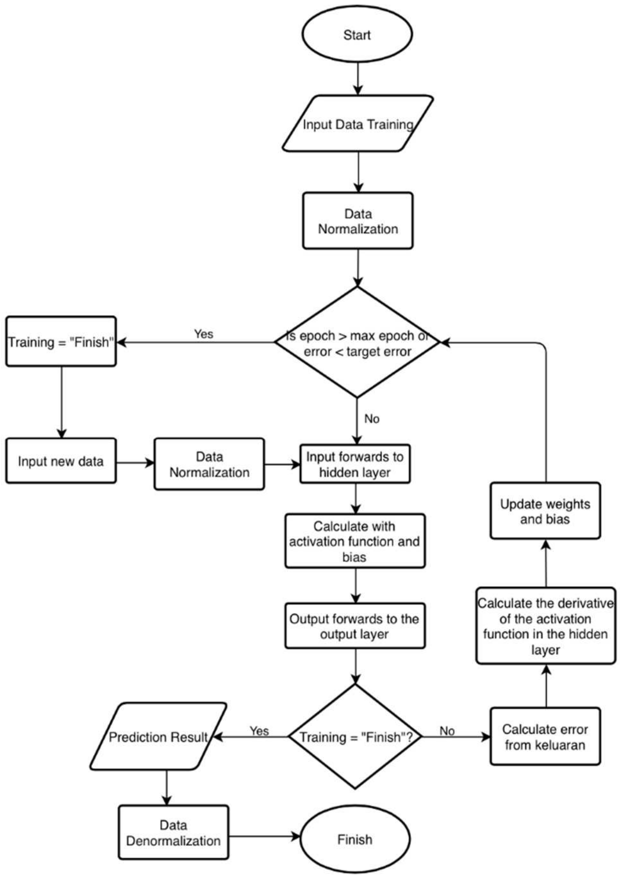

Fig. 2 ANN Flowchart

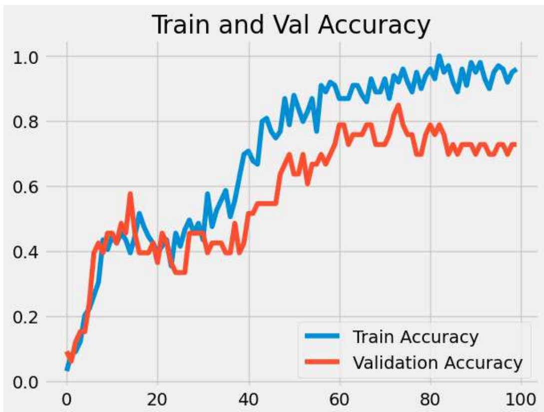

Fig. 3 Accuracy Training and Accuracy Validation

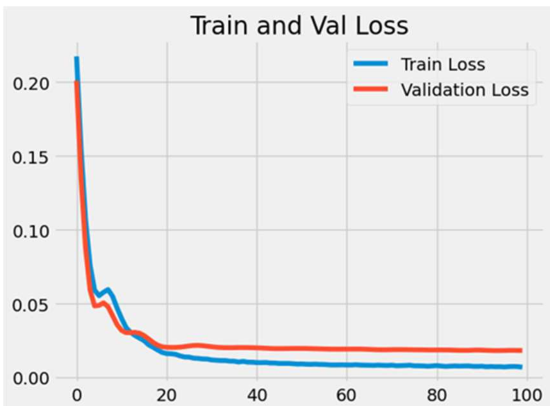

Fig. 4 Loss Training and Loss Validation

B. *Design of FerSys Application*

FerSys Application has a system architecture shown in Fig. 5. The farmer requests data from the server using a smartphone. The server processes the data using the database, machine learning, and API. Then, the processing results are sent to the user's smartphone.

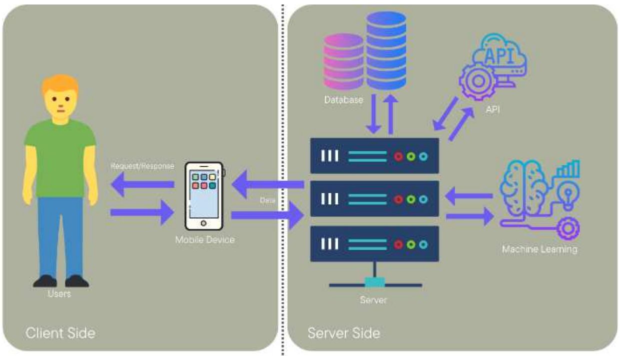

Fig. 5 System Architecture

FerSys has two user actors, the Owner and Supervisor. Each actor is described in Table II.

TABLE II
ACTOR IDENTIFICATION

No.	Actor	Description
1	Owner	Actors with the owner role have the authority to view weather forecasts and fertilization recommendation results, manage supervisor data, and view fertilization history reports.
2	Supervisor	Actors with supervisor roles can view weather forecasts, fertilization recommendation results, add fertilization time, and view fertilization history.

Based on the identification of user requirements, the system use case diagram is shown in Fig. 6.

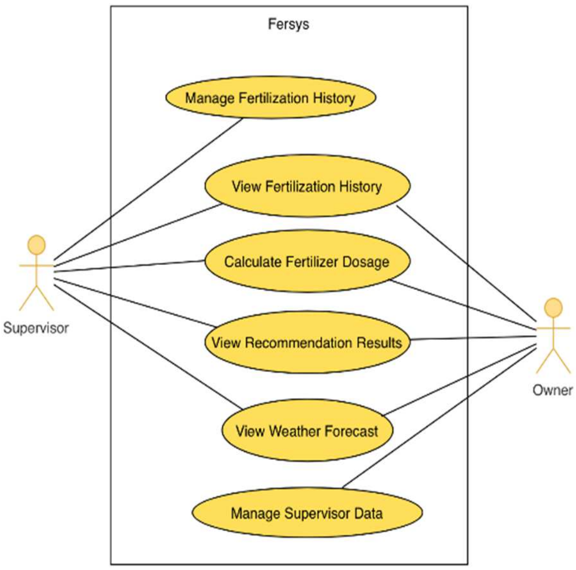

Fig. 6 Use Case Diagram

The database structure used in the FerSys application has five tables, which consist of a user table, fertilizer table, garden table, fertilization table, and rainfall table, as shown in Fig 7.

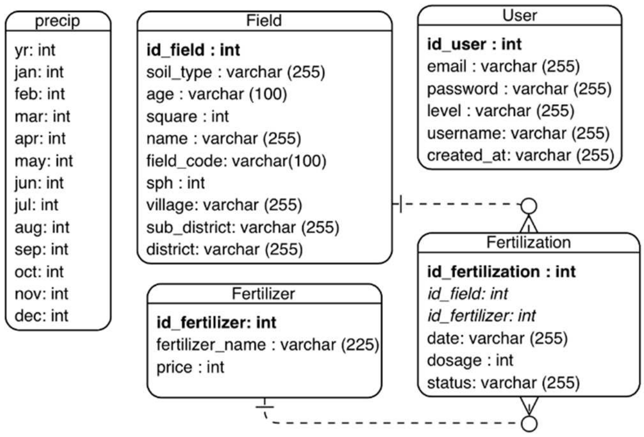

Fig. 7 Entity Relation Diagram

III. Result and Discussion

The results of the FerSys application implementation are shown in Fig 8, Fig 9, Fig 10, Fig 11, Fig 12, and Fig 13. Fig 8 recommends the oil palm fertilization period this year; Fig 9 is future fertilization recommendations for 2026. This recommendation comes from rainfall prediction or forecasting using the ANN algorithm. The results of rainfall prediction are shown in Fig 10, and the history of fertilization time is shown in Fig 11. Besides the recommendation of fertilization period, this mobile app has a feature for dose recommendation for oil palm, shown in Fig 12, and the weather information is also shown in Fig 13.

Fig. 8 Recommendation for oil palm fertilization period this year

Fig. 9 Recommendation for oil palm fertilization period in the future (2026)

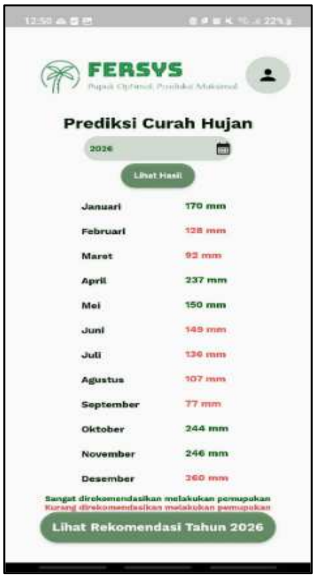

Fig 10 Rainfall prediction and History of fertilization time

Fig 11 History of fertilization time

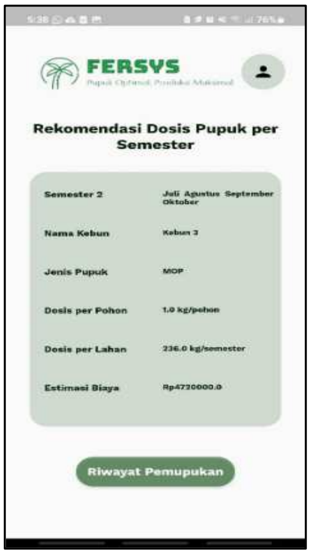

Fig. 12 Dose recommendation for oil palm

In the FerSys application, machine learning model testing and application testing were conducted. The machine learning testing employs the Artificial Neural Network (ANN) method with an architecture consisting of:

- 12 input layers, assuming inputs from the previous 12 months,
- 360 hidden layers, which contain weights to perform computations for detecting hidden features and patterns and
- 12 output layers representing the predicted rainfall values for an entire year.

The evaluation results show a Mean Squared Error (MSE) of 0.0019981 and a Mean Absolute Percentage Error (MAPE) of 9.355%. Since the MSE value is close to zero (0) and the MAPE is below 10%, it can be concluded that the model is highly effective in predicting rainfall.

The relevant prediction results are for the year 2023, as the input data used is real historical data. However, for predicting rainfall in subsequent years, the input data consists of predicted values, requiring real data to ensure accurate future predictions. Data normalization supports the stability of the machine learning accuracy, where the input values are scaled within the 0-1 range.

In the application testing step, three types of tests are used in this research: Black Box testing, User Acceptance Testing (UAT), and usability testing. Based on the results of Black Box testing, it can be concluded that all test units were successfully executed. Based on the results of User Acceptance Testing obtained with 14 test classes, it was 100% successful execution. The following percentages are generated for the four test criteria based on the usability test results, as shown in Table III.

TABLE III
USABILITY TESTING RESULT

Criteria	Percentages
Usefulness	100%
Ease of Use	80%
Ease of Learning	100%
Satisfaction	100%

Fig. 13 The weather information

The Plantation Management System is beneficial for monitoring activities in oil palm plantations to enhance productivity. The monitored activities include irrigation, fertilization, planting, and harvesting. With advancements in technology, plantation management systems can integrate machine learning algorithms to expand their features, including rainfall prediction[25], [26], yield prediction, and palm oil price forecasting [28] using algorithms such as Artificial Neural Networks (ANN) and Support Vector Machines (SVM). Meanwhile, oil palm tree counting using GPS images [29] or drone imagery [30], [31], with identification algorithms such as Convolutional Neural Networks (CNN) and YOLO (You Only Look Once).

The tree-counting process begins with identifying oil palm trees from GPS or drone images. This identification can also be used to assess the health condition of the oil palm trees, determining whether they are healthy or unhealthy. This is beneficial for taking corrective actions on unhealthy trees, such as evaluating whether the issue is due to inadequate fertilization, improper irrigation, or other factors

The Fersys application is part of a plantation management system designed to provide fertilization recommendations for oil palm plantations. These recommendations are based on annual rainfall conditions. The Fersys application predicts rainfall for the desired year using the Artificial Neural Network (ANN) algorithm, trained with BMKG data from 2018-2022. The ANN algorithm identifies months with optimal rainfall levels for oil palm trees (150-250 mm per month). By providing fertilization schedule recommendations, it is expected that proper fertilization timing can enhance oil palm productivity.

Additionally, the Fersys application includes information on fertilizers and precise fertilizer dosage calculations for oil palm trees. Based on application testing, supervisors and plantation owners have confirmed that Fersys meets their needs, effectively providing fertilization timing and dosage recommendations.

IV. Conclusion

The FerSys application helps users know the optimal time recommendation for fertilizing oil palms. Moreover, this application also allows users to record the history of fertilization done in the field. In developing this application, the method implemented is Artificial Neural Network (ANN). The model evaluation results show that the MSE and MAPE values are small, namely, the MSE value of 0.0019981 and the MAPE value of 9.355%. Black Box and User Acceptance Test (UAT) test results show that the application functionality runs well. Application development has also met the needs and expectations of users, both oil palm plantation owners and supervisors. Based on the usability testing results, users agree that the FerSys application can help provide recommendations for fertilization periods and doses.

The recommendation system for mobile-based oil palm fertilization is one of the other oil palm applications. There is also a recommendation system for mobile-based oil palm plantation periods and harvesting forecasting applications. So, future work will combine all these applications into a monitoring system for oil palm productivity.

Acknowledgment

We thank Mr. Edy Rahmanto from the Meteorology, Climatology and Geophysics Agency, Mr. Lamdamatra Arliyando from CV Drone Tani, and Mr. Akson Bramantyo for providing data and assisting with the research process.

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