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WEB-BASED RICE HARVEST PREDICTION SYSTEM USING FUZZY MAMDANI METHOD: A CASE STUDY IN MAGELANG CITY

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ABSTRACT

This study discusses the application of the Fuzzy Inference System method to predict rice yields in Magelang City as an effort to support food security planning. The data used included harvest area, production, and productivity with the period 2021–2022 as training data and 2023–2024 as test data. The prediction process is carried out through the stages of fuzzification, formation of fuzzy rules, inference using min–max operators, and defuzzification using the centroid method. The prediction system is designed to be web-based so that it can be used by farmers, government agencies, and related parties in decision-making. The results of the study show that the Fuzzy Mamdani method is able to produce predictions that are close to actual data with a low error rate. For example, the prediction of 109.20 tons in a harvest area of 18 Ha is close to the actual data of 106.56 tons, and an RMSE value of 1.43 tons is obtained which is better than the seasonal naïve and linear regression methods. With stable accuracy and flexibility in updating regulations, this system is suitable for use as an agricultural planning tool, especially for food distribution strategies, planting planning, and rice stock management in Magelang City.

Keywords: *Fuzzy mamdani, Rice harvest prediction, Information system, Defuzzification, Magelang City.*

INTRODUCTION

Rice is the main food commodity in Indonesia and plays a strategic role in maintaining national food security. The stable availability of rice is strongly influenced by the level of rice production each year. Harvested land area is one of the main factors determining the amount of production output. In addition, crop productivity also affects the quality and quantity of the harvest. Therefore, improving production, harvested area, and productivity must continue to be prioritized. Changes in any of these factors can have a direct impact on the amount of rice production produced (Yuliyani et al., 2023).

Based on data from the Central Statistics Agency (BPS) of Magelang City in 2016–2023, the area of rice harvest land in Magelang City has decreased significantly. In 2016, the harvested land area was recorded at 534 hectares, while in 2023 there will only be 135 hectares left. The decline of 399 hectares or around 74.72% was mainly due to the conversion of agricultural land into residential and industrial areas. This condition has a direct impact on the decrease in the amount of rice production, although the productivity value (tons/ha) tends to increase every year (Aziz, 2024).

The decline in harvest land that is not balanced with a significant increase in production poses challenges in agricultural sector planning. Local governments and related agencies need accurate information about rice yield estimates in order to develop appropriate policies, such as distribution planning, stock management, and anticipation of production shortages. For farmers, crop prediction information is also important to support planting activity planning and crop management (Nuraini et al., 2025).

In the development of information technology, the use of computing-based systems and data processing is becoming increasingly important in supporting decision-making in the agricultural sector (Swasono et al., 2023). Information technology allows the processing of agricultural historical data faster, systematic, and accurate, so that it can produce predictive information that is useful for local governments and farmers. The integration of agricultural statistical data with artificial intelligence-based computational methods and decision support systems is one of the solutions to deal with complexity and uncertainty in agricultural production planning (Zulfa et al., 2022).

Rice yield predictions cannot always be determined with certainty because they are influenced by uncertain and varied data, such as harvest area and productivity. Therefore, a method is needed that is able to handle the uncertainty of the data. One approach that can be used is *Fuzzy Inference System* (FIS), especially the Mamdani method (Zulfa et al., 2022a).

The Fuzzy Mamdani method has the advantage of modeling vague and uncertain problems by using linguistic rules that resemble human thinking. This method is widely used in prediction systems because of its simple structure and its ability to process numerical data into more flexible decisions. By utilizing the Fuzzy Mamdani method, it is hoped that rice yield prediction can be done more accurately and easily understood (Septyono et al., 2023).

Based on these problems, this study is focused on the application of the Fuzzy Mamdani method as part of an information technology-based prediction system to predict rice yield in Magelang City by utilizing harvest area and productivity data. The results of this research are expected to be an effective decision-making tool in the agricultural sector, especially in rice production planning in Magelang City (Septyono et al., 2023).

RESEARCH METHODS

The methodology applied in this research consists of several important stages, namely data collection, implementation of prediction methods, system development, and evaluation of the prediction results. The data collection process was carried out using secondary data obtained from the Central Statistics Agency (BPS) of Magelang City. The data used in this study include information related to harvested land area, rice production, and rice crop productivity. Furthermore, the collected data were processed and analyzed using prediction methods to estimate future rice production trends. After the prediction process was completed, the system was developed and tested to measure the accuracy and effectiveness of the prediction results. Through these stages, the study aims to provide reliable information that can support decision-making in the agricultural sector, particularly in maintaining rice availability and food security.

The data that has been collected is then processed using an information technology-based computing system to ensure that the data processing process takes place in a structured, accurate, and efficient manner. Data processing and analysis was carried out by applying the Mamdani Fuzzy Inference System (FIS) method which was implemented in a computer-based prediction system. The stages of the FIS Mamdani method include the fuzzification process, the formation of fuzzy rules (fuzzy rule base), the inference process using min–max operators, and defuzzification using the centroid method to produce predictive values of rice yield.

The development of the prediction system is carried out with a software engineering approach using the Waterfall, which includes the stages of needs analysis, system design, system implementation, and testing (Rahayu et al., 2024). At the implementation stage, the Fuzzy Mamdani is integrated into an information technology-based prediction system so that it is able to process input data automatically and produce prediction outputs that can be used as information to support decision-making.

The evaluation of the prediction results was carried out by comparing the prediction value generated by the system with the actual data using Mean Squared Error (MSE). The use of MSE aims to quantitatively measure the level of prediction error so that the level of accuracy of the developed system can be known. With this information technology-based methodology, it is hoped that the prediction system built will be able to produce predictions of rice yields that are accurate, efficient, and can be used as a decision support system in the agricultural sector, especially in rice production planning in Magelang City.

RESULTS AND DISCUSSION

Results

Rice Production Prediction System Design Display

The system interface was designed to support the implementation of the Fuzzy Mamdani method in a structured and user-friendly manner. Each page in the system has a specific function, starting from user authentication, data management, rule management, prediction processing, prediction history, and administrator management. The following figures present the main interface design of the rice harvest prediction system developed in this study.

The results of the design of the rice production prediction system in Magelang City are as follows:

Login Page Rice Harvest Prediction Using Fuzzy Mamdani

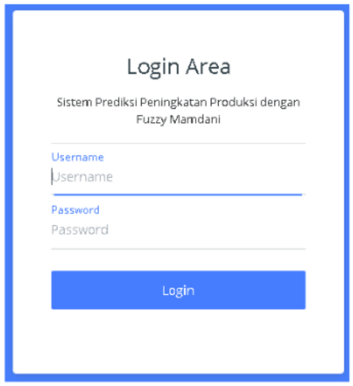

Figure 1. Login Area

Figure 1 shows the login page of the rice harvest prediction system using the Fuzzy Mamdani method. This page serves as the initial access point for users before entering the main system. Through this page, users are required to enter valid account credentials so that the system can ensure that only authorized users are able to access production data, rule data, prediction features, and administrative menus.

Dashboard Page

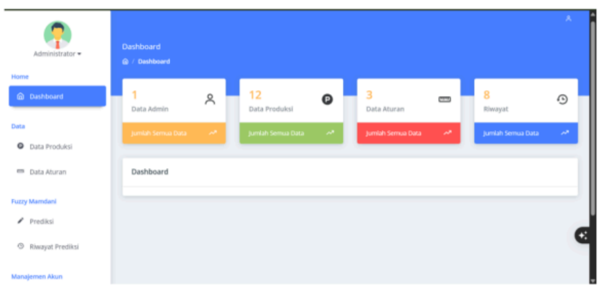

Figure 2. Dashboard Page

Figure 2 presents the dashboard page of the rice harvest prediction system. This page functions as the main interface after the user successfully logs in. The dashboard provides an overview of the available system menus and helps users navigate the main features, including production data management, fuzzy rule management, prediction processing, prediction history, and administrator data management.

Production Data Page

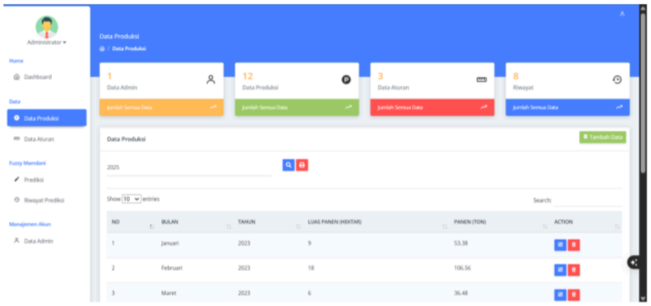

Figure 3. Production Data Page

Figure 3 displays the production data page, which is used to manage rice production data in the system. This page presents information related to harvest area, production, and productivity, which are important data components in the prediction process. Through this page, users can view, organize, and manage the historical production data required by the Fuzzy Mamdani-based prediction model.

Add page on Production Data tab

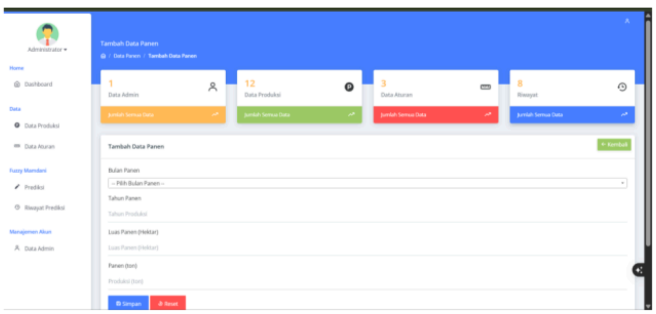

Figure 4. Add Data Page on the Production Data tab

Figure 4 shows the add data page on the production data tab. This page allows users to input new production data into the system, including harvest area, actual production, and related productivity information. The availability of this feature makes the system more flexible because users can update the dataset according to the latest agricultural conditions.

Rules Data Page

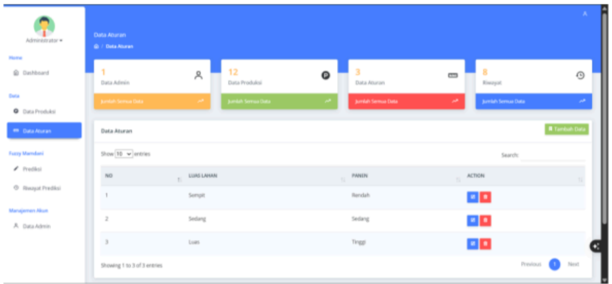

Figure 5. Rules Data Page

Figure 5 presents the rules data page used to manage the fuzzy rule base in the prediction system. The rules displayed on this page represent the relationship between input conditions, such as harvest area, and output conditions, namely predicted rice production. This page is essential because the accuracy of the Fuzzy Mamdani model depends strongly on the relevance and consistency of the rules used in the inference process.

Tanbah Page on the Rules Data Tab

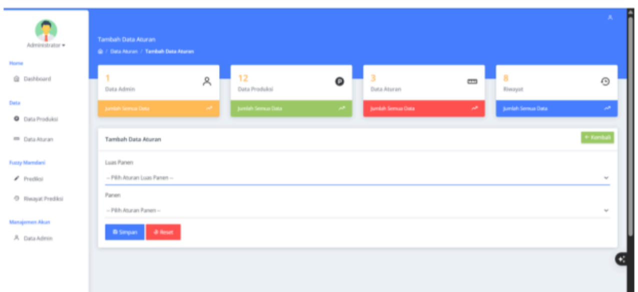

Figure 6. Add Data page on the Rules Data tab

Figure 6 shows the add data page on the rules data tab. This page is used to add new fuzzy rules to the prediction system. Through this feature, users or administrators can adjust the rule base when there are changes in agricultural conditions, data patterns, or expert considerations, so that the prediction model remains relevant and adaptable.

Prediction Page

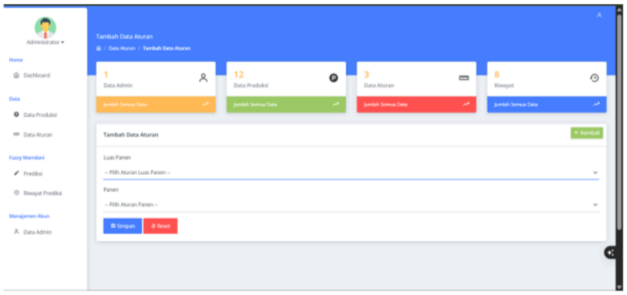

Figure 7. Prediction Page

Figure 7 presents the prediction page of the rice harvest prediction system. This page is the main feature where users enter the required input data, such as harvest area, to obtain predicted rice production results. The prediction output is generated through the Fuzzy Mamdani process, which includes fuzzification, rule evaluation, inference, aggregation, and defuzzification.

Prediction History Page

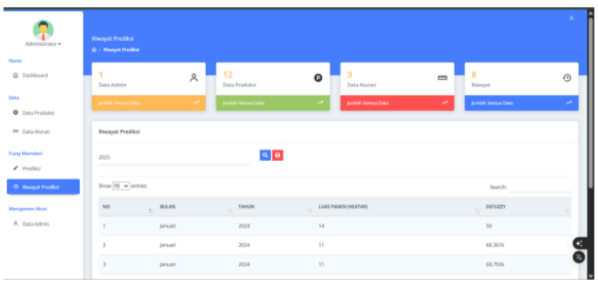

Figure 8. Prediction History Page

Figure 8 shows the prediction history page. This page records and displays the prediction results that have been generated by the system. The availability of prediction history helps users review previous prediction results, compare them with actual data, and evaluate the consistency of the system in supporting agricultural planning and decision-making.

Admin Data Page

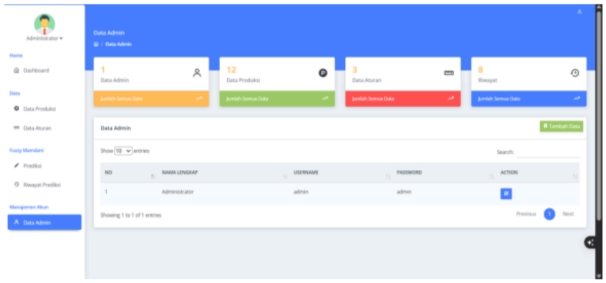

Figure 9. Admin Data Page

Figure 9 presents the admin data page, which is used to manage administrator information in the system. This page supports user management activities, particularly for controlling access to system features. By providing an admin management feature, the system can maintain data security and ensure that system operations are handled by authorized users.

Add Data Page on the Admin Data Tab

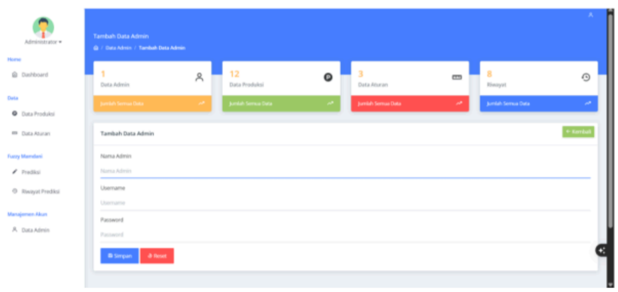

Figure 10. Add Data Page on the Admin Data Tab

Figure 10 shows the add data page on the admin data tab. This page allows the system administrator to add new admin accounts when needed. This feature is useful for managing system access, especially when the prediction system is used by more than one authorized officer or institution involved in rice production planning.

Discussion

System Testing

System testing is a crucial stage in this study because it serves to ensure that the information technology-based rice harvest prediction system developed is able to run in accordance with the design and objectives of the research. At this stage, the system is not only tested in terms of software functionality, but also in terms of its computational ability to process agricultural data accurately and consistently. The use of information technology allows the process of fuzzy calculations, data management, and evaluation of prediction results to be carried out automatically, structured, and reproducible (Tauhid et al., 2025).

System testing was conducted using actual rice harvest data from Magelang City for the period 2023–2024, obtained from the Central Statistics Agency (BPS) of Magelang City (Aziz, 2024). The dataset comprises eight harvesting periods across four seasons per year, with harvest area as the primary input variable to the Fuzzy Mamdani Inference System and rice production as the reference output. Table 1 presents the full test dataset along with the corresponding average productivity values used as the basis for system evaluation.

Table 1. Comparison of Prediction Results and Actual Data

Nr.	Month/ Year	Item	Area (Ha)	Production (ton)	Average (ton/Ha)
1	January 2023	Unit	9,00	53,38	5,93
2	April 2023	Unit	18,00	106,56	5,92
3	July 2023	Unit	6,00	36,48	6,08
4	October 2023	Unit	13,00	79,04	6,08
5	January 2024	Unit	15,00	93,60	6,24
6	April 24	Unit	6,00	37,44	6,24
7	July 2024	Unit	7,00	44,80	6,40
8	October 2024	Unit	11,00	70,40	6,40
	Total		**87,00**	**521,50**	**6,16**

Source: Primary Data Processing Results, 2025

Table 1 shows that rice harvest area in Magelang City during the test period ranged from a minimum of 6.00 Ha (April 2024 and July 2023) to a maximum of 18.00 Ha (April 2023), reflecting significant seasonal variability in planted area. Total harvested area across eight periods reached 87.00 Ha, with cumulative production of 521.50 tons and an overall average productivity of 6.16 ton/Ha. Notably, average productivity showed a consistent upward trend across the observation period, increasing from 5.92–5.93 ton/Ha in the first half of 2023 to 6.40 ton/Ha in the second half of 2024, indicating gradual improvement in per-hectare yield despite declining total harvest area. This productivity trend aligns with national intensification efforts and provides a reliable basis for evaluating the accuracy and consistency of the Fuzzy Mamdani prediction system under real field conditions.

The results of the testing of the Mamdani Fuzzy Inference System (FIS)-based harvest prediction system are presented as a key stage in assessing the quality of the research design. This test shows that the developed computer-based system is capable of translating numerical data on crop area and productivity into predictive information through fuzzy mechanisms integrated in the system (Septyono et al., 2023). Thus, the tests not only prove that the system is technically running, but also confirm the compatibility between the computational model used and the agronomic reality in the field.

The tests conducted in this study focus on three fundamental aspects, namely the functional validity of the system, the accuracy of predictions on actual data, and the stability of the system in the face of variations in input data (Saleh, 2024). Functional validity indicates that each system module, from data input, fuzzy inference processes, to prediction outputs, can run according to the specifications for which it was designed. The accuracy of the prediction was analyzed by comparing the output of the system with the actual production data, while the stability of the system was tested through the consistency of the prediction results at various variations in the harvest area (Arifin et al., 2024).

As a form of implementation of information technology-based testing, the system automatically generates prediction outputs and presents them in the form of numerical data that can be analyzed further (Lutfi et al., 2024). The comparison between the results of the system prediction and the actual data of rice production is presented in Table 2 below.

Table 2. Comparison of Prediction Results and Actual Data

Moon	Harvest Area (Ha)	Actual Production (Tons)	FIS Mamdani Prediction (Ton)	Differences	Squirrel²
January	9	53,38	56,37	-2,99	8,94
February	18	106,56	109,2	-2,64	6,97
March	6	36,48	37,1	-0,62	0,38
April	13	79,04	80,15	-1,11	1,23
May	15	93,6	95,4	-1,8	3,24

Source: Primary Data Processing Results, 2025

Table 2 presents the comparison between actual rice production data and the prediction results generated by the Fuzzy Mamdani system. The table includes monthly test data consisting of harvest area, actual production, predicted production, difference values, and squared errors. The results indicate that the predicted values are relatively close to the actual production data, with small differences in each month. This finding suggests that the Fuzzy Mamdani method is able to produce stable and reasonably accurate predictions for rice production based on harvest area data (Fairus et al., 2023).

Comparison with Existing Literature

The prediction results of this study are consistent with and extend findings from prior research on Fuzzy Mamdani-based agricultural prediction systems. Septyono et al., (2023) applied the Mamdani method for rice production prediction in Sumatra and reported comparable prediction accuracy using harvest area as the primary input variable, affirming that the method generalizes well across different agroecological regions. (Zulfa et al., (2022) conducted a comparative analysis of statistical approaches and Fuzzy Mamdani for rice productivity prediction and found that the fuzzy approach yields more contextually appropriate outputs in conditions characterized by limited and seasonal data, which is precisely the condition faced in Magelang City given its declining harvest area. Burhanuddin, (2023) further demonstrated that among the three major FIS variants, Tsukamoto, Mamdani, and Sugeno, the Mamdani method delivers competitive performance in predicting rice productivity across Indonesian provinces, with the advantage of producing linguistically interpretable rules that are meaningful to agricultural stakeholders. The RMSE of 1.43 tons achieved in this study is lower than the error margins reported by comparative benchmark methods (seasonal naïve and linear regression), confirming the superiority of the fuzzy approach for this type of small-scale regional prediction problem. Nasution & Prakarsa, (2020) similarly showed that Mamdani fuzzy logic effectively supports production volume decisions under uncertain input conditions, reinforcing the applicability of this study's approach. Furthermore, Nuraini et al., (2025) noted that more complex machine learning models do not always outperform simpler rule-based fuzzy systems when data is seasonal and spatially constrained, which supports the choice of Mamdani FIS as a computationally efficient yet accurate solution for Magelang City's agricultural context.

The novelty of this study is threefold. First, this research is the first to apply Fuzzy Mamdani FIS specifically to rice yield prediction in Magelang City, an urban-peri-urban municipality where agricultural land has contracted by 74.72% over seven years due to land conversion (Siagian et al., 2025; Wibowo & Mukammila, 2022). This context, characterized by small, fragmented, and rapidly diminishing harvest areas, differs fundamentally from the rural and plantation-scale settings addressed by prior studies (Fairus et al., 2023; Zulfa et al., 2022), making the development of a prediction system tailored to these conditions a meaningful contribution to regional food security management. Second, this study integrates the FIS Mamdani model into a fully web-based information system built using the Waterfall development methodology (Rahayu et al., 2024), enabling end-users including government agencies, farmers, and planners to perform real-time predictions and update the fuzzy rule base without specialized technical knowledge. The system's modular architecture, encompassing authentication, data management, rule management, prediction, and history logging, distinguishes it from prior implementations that deliver the fuzzy model as a standalone calculator or desktop application (Tauhid et al., 2025). Third, the evaluation framework employs RMSE benchmarked against two baseline methods (seasonal naïve and linear regression), providing a rigorous quantitative basis for assessing the system's predictive advantage, an evaluation design not consistently applied in comparable studies (Burhanuddin, 2023).

From a global perspective, this study contributes to the growing literature on soft computing applications in food security governance, particularly in developing economies experiencing rapid urbanization and agricultural land loss. The web-based FIS Mamdani system developed here offers a replicable model for small-scale agricultural decision support in regions where data availability is limited and technical capacity is constrained (Wulandari et al., 2024). The use of information technology to streamline fuzzy calculations, rule management, and prediction history represents a practical advancement in how computational intelligence tools can be made accessible to non-specialist users in the agricultural sector (Swasono et al., 2023). Yuliyani et al., (2023) emphasized that rice farming efficiency in Indonesia is highly sensitive to seasonal dynamics, and this system directly addresses that sensitivity by allowing periodic rule-base updates aligned with shifting agricultural calendars. The transparent linguistic rule structure of the Mamdani method also supports explainability, a property increasingly valued in AI-assisted policy tools, as it allows government officials and extension workers to verify and interpret prediction logic without black-box concern (Nasution & Prakarsa, 2020; Tauhid et al., 2025). Looking forward, the system architecture developed in this study provides a scalable foundation for integration of additional agronomic variables such as rainfall, soil type, and fertilizer inputs, which would further improve prediction accuracy and extend the system's applicability to broader food distribution planning and rice stock management in Indonesia (Nuraini et al., 2025; Swasono et al., 2023).

CONCLUSION

Based on research and discussion, the Mamdani Fuzzy Inference System (FIS) method has proven to be effective in predicting rice yields in Magelang City through the stages of fuzzification, formation of fuzzy rules, min–max inference, and centroid defuzzification, with prediction results that are close to actual data so that they are able to handle the uncertainty of agricultural data. In addition, web-based prediction systems are successfully designed to manage production data and rules, make predictions, and display results and history in a structured manner so that the process becomes faster, consistent, and easier to use; testing using Mean Squared Error (MSE) shows a relatively low error rate which indicates good accuracy and the feasibility of the system as a decision-making aid, and this system is considered beneficial for related agencies, farmers, and policy makers in distribution planning, rice stock management, and planting planning for the next period.

The suggestions given focus on the further development of the system and subsequent research, namely adding input variables (e.g. rainfall, rice varieties, soil conditions, and fertilizer use) to make predictions more accurate and represent field conditions, making comparisons with other methods such as different fuzzy or machine learning-based forecasting to find out the most optimal approach, improving the interface, especially visualization of results (e.g. crop trend graphs or automated reports) so that it is easy for non-technical users to understand, expand the scope of the research area so that the system can be applied in other areas with different agricultural characteristics, and make this research a reference for the development of a decision support system for the agricultural sector based on fuzzy logic.

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