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MAMDANI FUZZY LOGIC ANALYSIS FOR ANIMAL MEDICINE STOCK OPTIMIZATION

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Abstract: The management of veterinary drug stocks at the Veterinary Clinic Technical Implementation Unit (UPTD) of the North Sumatra Province Plantation and Livestock Service faces obstacles in the form of discrepancies between supply and demand, resulting in excess stock and budget waste. Uncertain demand for drugs is a factor that complicates decision-making in stock provision. This study aims to optimize drug stock management using the Mamdani fuzzy logic method, which is capable of handling data uncertainty and modeling information linguistically. Three input variables are used, namely initial stock, demand, and number of visits, with the output being the final stock. The process involves fuzzification, inference based on IF–THEN rules, and defuzzification using the centroid method. The results show that the developed system has a good accuracy level with a MAPE value of 17.52%, which means that this model is effective in providing optimal and efficient drug stock recommendations in a veterinary clinic environment.

Keywords: fuzzy mamdani; optimization; animal drug stock.

Abstrak: Pengelolaan stok obat hewan di UPTD Klinik Hewan Dinas Perkebunan dan Peternakan Provinsi Sumatera Utara menghadapi kendala berupa ketidaksesuaian antara jumlah persediaan dengan permintaan, sehingga menimbulkan kelebihan stok dan pemborosan anggaran. Permintaan obat yang tidak pasti menjadi faktor yang menyulitkan pengambilan keputusan dalam penyediaan stok. Penelitian ini bertujuan untuk mengoptimalkan pengelolaan stok obat menggunakan pendekatan logika fuzzy Mamdani yang mampu menangani ketidakpastian data dan memodelkan informasi secara linguistik. Tiga variabel input digunakan, yaitu stok awal, jumlah permintaan, dan jumlah kunjungan, dengan output berupa stok akhir. Proses yang dilakukan mencakup fuzzifikasi, inferensi berdasarkan aturan IF–THEN, dan defuzzifikasi menggunakan metode centroid. Hasil penelitian menunjukkan bahwa sistem yang dibangun memiliki tingkat akurasi yang baik dengan nilai MAPE 17,52%, yang berarti model ini efektif dalam memberikan rekomendasi stok obat secara optimal dan efisien di lingkungan klinik hewan.

Kata kunci: fuzzy mamdani; optimasi; stok obat hewan.

INTRODUCTION

Optimal veterinary drug stock is important for veterinary clinics and farms. The problems that arise include two contradictory issues, namely excess drug stock and shortages of certain drugs.

Excess drug stock can lead to waste of resources. On the other hand, drug shortages can hamper the animal treatment process and pose a risk to the availability of health services [1].

Problems were found at the Animal Clinic Technical Implementation Unit of the North Sumatra Province Plantation and Livestock Service, where managers had difficulty determining the amount of veterinary medicine that should be available to meet animal needs. The clinic had an excess stock of veterinary medicine, resulting in a waste of budget funds.

In research conducted by Bowo et al [2] with the title "Fuzzy Mamdani for Rice Production Recommendations Based on Supply Data and Demand (Case Study of PT XYZ)". This study found a problem, namely insufficient rice production with high demand, which would prevent the company from maximizing its profits. The difference between previous studies and the study to be conducted is the object of the study.

Then in another study conducted by Islamy et al [3] with the title "Weekly Tofu Stock Prediction Using the Mamdani Fuzzy Method." This study aims to predict weekly tofu stock using the Mamdani fuzzy method, while the author's research aims to optimize animal medicine stock.

Fuzzy logic is a mathematical framework that can overcome problems of uncertainty and imprecision through the use of membership degrees between 0 and 1 in decision making [4]. Fuzzy is known as fuzzy logic, which is a method of artificial intelligence. Artificial intelligence is an information system related to the modeling and storage of human intelligence in an information technology system [5].

Fuzzy logic is the preferred choice for decision making because it has several advantages, namely flexibility, a simple concept, the ability to apply expert knowledge, and several other advantages [6]. One of the most appropriate Fuzzy methods is the Mamdani Fuzzy logic method. The advantage of the Mamdani Fuzzy method is its ability to translate linguistic conditions into clear numerical outputs. Mamdani Fuzzy will produce definite outputs based on the circumstances that occur [7].

In previous research conducted by Luthfi et al [8] which examines rice stock determination using fuzzy Mamdani. In this study, fuzzy Mamdani has been proven to make rice stocks more effective. It can even optimize rice ordering and checking.

In another study conducted by Muntaja and Sriani [9], who researched the optimization of various types of cell phone spare parts using fuzzy Mamdani. Fuzzy Mamdani has once again proven capable of producing accurate optimization levels with a MAPE of 11%.

Al-faruq and Hindarto [10], conducting research on the implementation of fuzzy logic in stock optimization using the Mamdani fuzzy method. In his research, the accuracy of the data obtained was 83 percent, proving that Mamdani fuzzy is appropriate for optimizing stock. The above research proves that the Mamdani fuzzy method is flexible, effective, and accurate. This study aims to analyze the application of Mamdani fuzzy logic in the process of optimizing animal

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medicine.

METHOD

This study uses a quantitative approach with the Mamdani fuzzy logic method to optimize drug stocks. The data used are historical data on initial stocks, demand, and the number of visits to the He-wan Clinic UPTD of the North Sumatra Province Plantation and Livestock Service. The following are the stages of the research conducted:

The preliminary study involved conducting observations and interviews with clinic staff to understand the stock management process and identify existing problems.

Data collection was carried out by gathering historical data on the five most frequently used types of veterinary drugs (Vetadryl, Bsanplex, Intramox, Revolution, and Mectisan). The data collected included Initial Stock (units), Number of Requests (units), and Number of Visits (patients).

Fuzzy System Design: First, define three input variables (Initial Stock, Demand, Number of Visits) and one output variable (Final Stock). Second, the fuzzification stage involves determining the membership function and fuzzy set for each variable. The function used is a triangular curve (trimf). Third, create a rule base with 27 IF-THEN rules that represent the decision-making logic. Fourth, perform inference and defuzzification to apply the min method for inference and the centroid method for defuzzification [11]. The centroid method has the following formula:

$$WA = \frac{\sum(\mu i \, . zi)}{\sum \mu i} \quad (1)$$

Where:

µi : Degree of membership of inference results
zi : Center point of related fuzzy sets

Implementation and Testing by applying the Mamdani fuzzy model using MATLAB software. Testing the model with historical data and comparing the results with actual data.

Accuracy Evaluation by calculating the Mean Absolute Percentage Error (MAPE) value to measure the accuracy level of the model. MAPE is obtained through the following formula:

$$MAPE = \left|\frac{A-P}{A}\right| x \ 100\% \quad (2)$$

Where:
A = Actual Value
P = Predicted Value

RESULT AND DISCUSSION

In performing the solution using fuzzy Mamdani, there are four stages carried out to obtain the optimization results. The stages are as follows.

Fuzzification and membership functions

At this stage, input and output variables are converted into fuzzy values. termination of ranges and domains for Each fuzzy set is based on historical data analysis collected from the Animal Clinic Technical Implementation Unit (UPTD), as well as consultation with clinic management. This ensures that the model can reflect actual operational conditions. For example, the domain range for “Initial Stock” is determined from the minimum and maximum stock values recorded during the observation period. In this study, the researchers used triangular functions for each variable.

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Table 1. Fuzzy Sets

Function	Variable	Set	Range	Domain
Input	Initial Stock	Low	[0-1500]	[0 0 750]
		Medium	[0-1500]	[400 750 1100]
		High	[0-1500]	[800 1500 1500]
	Demand	Low	[0-1000]	[0 0 500]
		Medium	[0-1000]	[300 500 700]
		High	[0-1000]	[500 1000 1000]
	Number of Visits	Low	[0-1100]	[0 0 600]
		Medium	[0-1100]	[300 600 900]
		High	[0-1100]	[600 1100 1100]
Output	Final Stok	Low	[0 850]	[0 0 400]
		Medium	[0 850]	[300 500 700]
		High	[0 850]	[500 850 850]

Table 1 shows the domains obtained from each variable, both input and ouput.

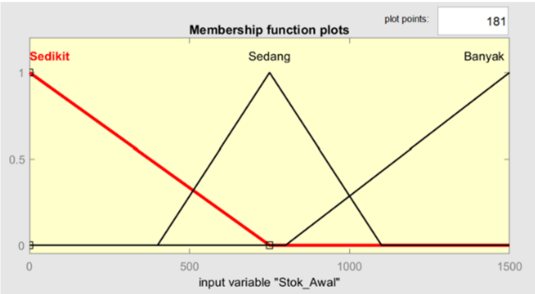

Figure 1. Membership Function of Initial Stock Variable

Figure 1 illustrates the membership function curve of the initial stock variable. The following is the formula for the initial stock membership function.

Initial Stock is Low

$$\mu Low(x) = \begin{cases} 0, & x \leq 0 or\ x \geq 750 \\ \dfrac{x-0}{0-0}, & 0 < x \leq 0 \\ \dfrac{750-x}{750-0}, & 0 < x < 750 \end{cases}$$

Initial stock is low [400 750 1100]

$$\mu Medium\ (x) = \begin{cases} 0, & x \leq 400\ or\ x \geq 1100 \\ \dfrac{x-400}{750-400}, & 400 < x \leq 750 \\ \dfrac{1100-x}{1100-750}, & 750 < x < 1100 \end{cases}$$

Initial stock is high [800 1500 1500]

$$\mu High\ (x) = \begin{cases} 0, & x \leq 800\ or\ x \geq 1500 \\ \dfrac{x-800}{1500-800}, & 800 < x \leq 1500 \\ \dfrac{1500-x}{1500-1500}, & 1500 < x < 1500 \end{cases}$$

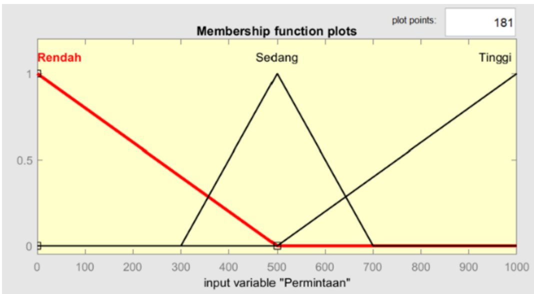

Figure 2 Variable Demand Membership Function

Figure 2 illustrates the membership function curve of the demand variable. The following is the formulation of the demand membership function.

Low demand [0 0 500]

$$\mu Low\ (x) = \begin{cases} 0, & x \le 0\ or\ x \ge 500 \\ \dfrac{x-0}{0-0}, & 0 < x \le 0 \\ \dfrac{500-x}{500-0}, & 0 < x < 500 \end{cases}$$

Demand is medium [300 500 700]

$$\mu Medium\ (x) = \begin{cases} 0, & x \le 300\ atau\ x \ge 700 \\ \dfrac{x-300}{500-300}, & 300 < x \le 500 \\ \dfrac{700-x}{700-500}, & 500 < x < 700 \end{cases}$$

Demand is high [500 1000 1000]

$$\mu High\ (x) = \begin{cases} 0, & x \le 500\ atau\ x \ge 1000 \\ \dfrac{x-500}{1000-500}, & 500 < x \le 1000 \\ \dfrac{1000-x}{1000-1000}, & 1000 < x < 1000 \end{cases}$$

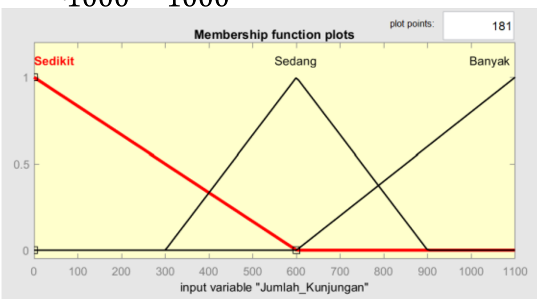

Figure 3 Membership Function of Number of Visits Variable

Figure 3 illustrates the membership function curve for the number of visits variable. The following is the formulation of the demand membership function.

Number of visits is low [0 0 600]

$$\mu Low\ (x) = \begin{cases} 0, & x \le 0\ or\ x \ge 600 \\ \dfrac{x-0}{0-0}, & 0 < x \le 0 \\ \dfrac{600-x}{600-0}, & 0 < x < 600 \end{cases}$$

Number of visits is medium [300 600 900]

$$\mu Medium\ (x) = \begin{cases} 0, & x \le 300\ or\ x \ge 900 \\ \dfrac{x-300}{600-300}, & 300 < x \le 600 \\ \dfrac{900-x}{900-600}, & 600 < x < 900 \end{cases}$$

Number of visits is high [600 1100 1100]

$$\mu High\ (x) = \begin{cases} 0, & x \le 600\ or\ x \ge 1100 \\ \frac{x-600}{1100-600}, & 600 < x \le 1100 \\ \frac{1100-x}{1100-1100}, & 1100 < x < 1100 \end{cases}$$

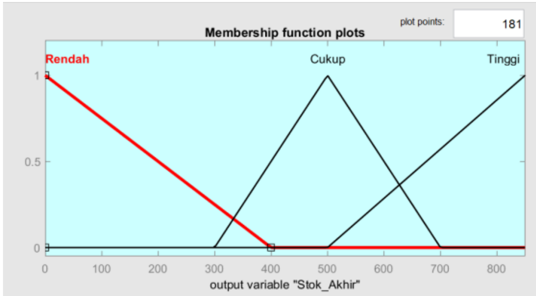

Figure 4 Final Stock Variable Membership Function

Figure 4 illustrates the membership function curve of the final stock variable. The following is the formulation of the ending stock membership function.

Low final stock [0 0 400]

$$\mu Low\ (x) = \begin{cases} 0, & x \le 0\ or\ x \ge 400 \\ \dfrac{x-0}{0-0}, & 0 < x \le 0 \\ \dfrac{400-x}{400-0}, & 0 < x < 400 \end{cases}$$

Medium final stok [300 500 700]

$$\mu Medium\ (x) = \begin{cases} 0, & x \le 300\ or\ x \ge 700 \\ \dfrac{x-300}{500-300}, & 300 < x \le 500 \\ \dfrac{700-x}{700-500}, & 500 < x < 700 \end{cases}$$

High final stok [500 850 850]

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$$\mu High\,(x) = \begin{cases} 0, & x \leq 500 \text{ or } x \geq 850 \\ \frac{x-500}{850-500}, & 500 < x \leq 850 \\ \frac{850-x}{850-850}, & 850 < x < 850 \end{cases}$$

The calculation of membership degrees in this study is triangular, which is commonly used in fuzzy logic methods. The following are the membership degree calculations for each type of drug used in the study.

Vetadryl

Initial stok

µHigh [1500] = $\frac{x-800}{1500-800}$, $800 < x \leq 1500$

$\frac{1500-800}{1500-800} = 1$

Demand

µHigh [970] = $\frac{x-500}{1000-500}$, $500 < x \leq 1000$

$\frac{970-500}{1000-500} = 0{,}94$

µ = 0,94

Number of visit

µHigh [1053] = $\frac{x-600}{1100-600}$, $600 < x \leq 1100$

$\frac{1053-600}{1100-600} = 0{,}906$

µ = 0,906

The results of the membership degree calculations for other types of drugs are summarized in the following table:

Table 2. Degree of Membership

Medicine Types	Degree of Membership		
	Initial stok	Demand	Number of visit
Bsanplex	µHigh = 1	µHigh = 0,65	µHigh = 0,672
Intramox	µHigh = 1	µMedium = 0,22 µHigh = 0,312	µMedium = 0,597 µHigh=0,242
Revolution	µMedium = 0,83 µHigh = 0,286	µLow = 0,592	µMedium = 0,606
Mectisan	µMedium = 0,83 µHigh = 0,286	µLow = 0,694	µLow= 0,693

Rule Base and Inference

The second stage of this research is the formulation of rules based on the fuzzy sets that were designed in the first stage. These rules are formulated using the IF-THEN logic approach, which links combinations of input variables (initial stock, demand, and number of visits) with output variables (final stock).

Table 3. Rule Base

No	Variable			
	Input			Output
	Initial stok	Demand	Number of visit	Final stok
R1	Low	Medium	Low	Low
R2	Low	Medi-um	Me-dium	Low
R3	Low	Low	High	Medi-um
R4	Low	Medi-um	Low	Low
R5	Low	Medi-um	Me-dium	Low
R6	Low	Medi-um	High	Low
..	……	…….	…….	……..
R27	High	High	High	High

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The third step of the Fuzzy Mamdani method is inference. Inference is performed by combining the rule base that has been compiled based on the fuzzy set of each variable. At this stage, the AND logic function represented by the MIN operator is used to determine the degree of truth of each rule. Inference from the data that has been created can be summarized in the following table.

Table 4. Inference

Drug	Rule	Output Fuzzy	α (min)
Vetadryl	R27	High	0.906
Bsanplex	R27	High	0.65
Intramox	R23	Low	0.22
Intramox	R24	High	0.22
Intramox	R26	High	0.312
Intramox	R27	High	0.242
Revolution	R10	High	0.592
Revolution	R19	High	0.286
Mectisan	R10	High	0.693
Mectisan	R19	High	0.286

Defuzzification

After all rules are inferred, the result is several truncated fuzzy sets. To obtain a single value, the centroid (Center of Gravity) method is used. This method calculates the center of mass of the inference area to produce a definite final stock value.

The results of data calculations using MAPE. MAPE stands for Mean Absolute Percentage Error. MAPE measures the average absolute error between the predicted value and the actual value, expressed as a percentage of the actual value. To measure the accuracy of the model, the Mean Absolute Percentage Error (MAPE) is calculated by comparing the actual stock value with the model's predicted value. The following are the MAPE calculation results for five types of drugs:

Table 5. MAPE values

type of drugs	Current Stock (A_i)	Prediction Stock (P_i)	% MAPE
Vetadryl	100	62	38.00 %
Bsanplex	250	229	8.40%
Intramox	500	404	19.20%
Revolution	150	138	8.00%
Mectisan	300	260	13.33%
Average			17.38%

With a MAPE value of 17.38%, this model can be categorized as "accurate" based on the MAPE accuracy scale. This value indicates that the developed Mamdani fuzzy system is capable of predicting and providing stock recommendations with an acceptable level of error and is useful in practice.

CONCLUSION

This study successfully applied Mamdani fuzzy logic to optimize animal medicine stocks at the Animal Clinic Technical Implementation Unit (UPTD) of the North Sumatra Province Plantation and Livestock Service. The model was constructed using three input variables (initial stock, demand, and number of visits) and one output variable (final stock) with a structured IF-THEN rule base. Testing results showed that this model has a good level of accuracy, with a MAPE value of 17.38%, which falls

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into the "accurate" category. The implementation of this model has proven to be able to provide more efficient stock recommendations, reduce the risk of excess stock, and assist clinic managers in making strategic decisions. Thus, Mamdani fuzzy logic is an effective and adaptive method for addressing uncertainty in inventory management.

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