Design a fuzzy inference system to determining superior commodities for create a village medium-term development plan

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Abstract. The Village RPJM, also known as the Village Medium Term Development Plan, is something that must be prepared very carefully. The Village RPJM, especially the Sukadamai village, currently uses intuition alone, even the data held by the village head is still not updated. So that the Village RPJM does not provide maximum results. Therefore, it is necessary to make an intelligent system that can help the village head in determining the potential commodities in Sukadamai village. The latest data with high precision was obtained with the help of the IPB PSP3 using drones and participant assistance. This intelligent system uses a Fuzzy Inference System (FIS) to determine the commodities that have potential in the town of Sukadamai. The input variables used in this study are 10. For the potential of the land and market potential, each of the 27 rules and for the potential of the citizens to produce 64 rules. In the next FIS process, it produces 27 rules to get a potential commodity, so the total rules obtained are 145 rules. Hopes that with this intelligent system, in making the Village RPJM, the village government can be more focused on developing superior commodities in the Sukadamai village.

Keyword: Commodity, Village RPJM, Fuzzy Inference System

1. Introduction

Law No. 6 of 2014 concerning Villages (Village Law) mandates the preparation of the Village Medium Term Development Plan (RPJM Desa) and the Annual Village Development Plan or what is called the Village Government Work Plan (Village RKP) to village government. The Village RPJM is a plan for village development activities for 6 (six) years, and the Village RKP as the elaboration of the Village RPJM is valid for 1 (one) year. The Village RPJM and Village RKP are the basis for rural development with the aim of making efforts to improve the quality of life and life for the highest welfare of rural communities [1].

In order for village development to work well and produce, village development must be planned, coordinated, time-bound, and following the specific conditions of the community and village area concerned. Besides, the implementation of village development involves the active role of the community, village officials, village institutions, institutions at the sub-district and district levels (or supra-village institutions), and others. It is also essential to monitor and evaluate the implementation of
village development so that the direction does not deviate from the lines set in the village development planning itself [1].

Center for Rural and Agricultural Development Studies (PSP3) is part of the Institute for Research and Community Service (LPPM) IPB. PSP3 aims to develop socio-economic sciences of agriculture (in the broad sense) through community empowerment research activities [2]. PSP3 IPB researched the Sukadamai Village in Bogor regarding the Village RPJM and the completeness of the Sukadamai Village data such as the number of residents, the level of education of residents, the occupation of the residents, land area, size of the house, and others. PSP3 conducts data collection using the help of drones and participants so that the data obtained is following the current situation of Sukadamai Village.

The village head who was elected was given three months to develop the village RPJM as of the inauguration of the village head. From the time given, the Village Head must immediately be able to make a Village RPJM that is following the current village situation. Therefore we need an intelligent system that can quickly process the amount of accurate data contained in the village. Potential expert systems in helping to determining superior commodities by predicting it, so that government efforts can be carried out effectively and efficiently. The existence of an expert system can facilitate work or even replace experts, combine the knowledge and experience of several experts and provide the expertise needed by a project that does not have experts [3].

Fuzzy Logic is a branch of artificial intelligence to build intelligent systems. Fuzzy logic is often used in problem-solving that explains the system not through numbers, but linguistically, or variables that contain uncertainty/uncertainty. These uncertain values are based on reasoning that combines numerical variables, linguistic variables, and rules [4]. Fuzzy logic is a precise way to map an input space into an output space [5].

Fuzzy logic is an extension of the many values of logic in the sense of the formation of fuzzy sets and fuzzy relations as a tool into a system with many logical values [6]. The strength of FIS relies on two important characteristics. First, they are able to handle linguistic concepts. Second, they are universal approximators able to perform nonlinear mappings between inputs and outputs [7].

A research about an apple grading study using fuzzy logic. In that study, it resulted in 89% correct accuracy [8]. Apples were classified based on their surface blemishes with a classification success of 96.6% using a multi-layer feed forward neural network classifier [9]. Use of artificial neural networks provides a powerful tool for sorting operations. However, it is also associated with high computational cost and uncertainty about the working procedure of the classifier. FL, on the other hand, involves less computation and has clear implementation and working schemes.

In the expert system research, the determination of the productivity of fragrant pandanus rice using fuzzy was carried out by Arkeman, resulting in a final accuracy of 88%. This shows that fuzzy logic can be used to determine the prediction of productivity of fragrant pandan rice in the village of Cianjur Village [10].

2. Materials and Methods
2.1. Data
The data in this study were obtained from PSP3. PSP3 obtains data using drones and participants, so the data provided by PSP3 is the latest and most complete data. Other data is obtained by conducting interviews with residents and experts. Data obtained in the form of raw data is used to assist in determining input parameters and data obtained in the form of membership functions and a collection of rules.

2.2. Methods
Fuzzy logic has been used extensively in decision support systems, for strategic planning, in industrial organizations to model Fuzzy Inference System (FIS) [11]. The strength of FIS relies on two important characteristics. First, they are able to handle linguistic concepts. Second, they are universal approximators able to perform nonlinear mappings between inputs and outputs [7]. The fuzzy rules of the system make use of fuzzy linguistic terms described by membership functions. These functions
capture the human expert’s conception of the linguistic terms. Fuzzy rules take the form IF (conditions) THEN (actions). Where conditions and actions are linguistic values applied to input and output variables respectively [5].

The Mamdani method is often known as the Max-min method. This method was introduced by Ebrahim Mamdani in 1975. Four steps are needed to get output [5]:

1. Formation of fuzzy sets
   In the Mamdani method, both input variables, and output variables are divided into one or more fuzzy sets.

2. Application function implications
   In the Mamdani method, the function implication used is min.

3. Composition of rules
   There are three methods used in doing fuzzy system inference, namely max, additive and probabilistic OR. If all propositions have been evaluated, the output will contain a fuzzy set that reflects the contribution of each proposition.

4. Defuzzification
   The input of the defuzzification process is a fuzzy set that is obtained from the composition of fuzzy rules, while the resulting output is a number in the fuzzy set domain in a certain range, so a specific crisp value must be taken as the output. There are several defuzzification methods in the composition of the Mamdani rules, namely center of gravity, mean of max, and bisector of the area as in the figure 1 [5].

![Figure 1. Defuzzification of Mamdani model [5].](image)

In this study using the center of gravity defuzzification. In this method, the crisp solution is obtained by taking the center point \( (x*) \) of the fuzzy region.

\[
x^* = \frac{\int x \mu_C(x) dx}{\int \mu_C(x) dx}
\]

(1)

\( x^* \) is the x-coordinate of center of gravity. \( \int x \mu_C(x) dx \) denotes the area of the region bounded by the curve \( \mu_C \).

\[
x^* = \frac{\sum_{i=1}^{n} x_i \mu_i(x_i)}{\sum_{i=1}^{n} \mu_i(x_i)}
\]

(2)

If \( \mu_C \) is defined with a discrete membership function, then CoG can be stated as equation (2).

3. Methodology
   The method used to design superior commodity intelligent system consists of several stages in full is presented in figure 2.
3.1. Knowledge Acquisition

Knowledge acquisition is needed to acquire knowledge, facts, and rules required by intelligent systems. Sources of knowledge in this study were obtained from data, farmers, Sukadamai villagers, and related journals. Based on knowledge acquisition that has been done, obtained four fuzzy inference systems. The first FIS is to determine the potential of citizens, the second FIS to determine market potential, the third FIS to determine the potential of the land and the last FIS is the determination of superior commodities. Each FIS has many input parameters, inference systems, and a set of rules.

The first FIS has four inputs, and the second and third FIS have three inputs. The output of the three FISs will be input for the fourth FIS. The following are the parameters that will be used in FIS in table 1-4.
Table 1. Description of input parameters for the first FIS.

| No | Parameter            | Unit   |
|----|----------------------|--------|
| 1  | Man                  |        |
| 2  | Quality of Education |        |
| 3  | Illness              |        |
| 4  | Age                  |        |

Table 2. Description of input parameters for the second FIS.

| No | Parameter | Unit |
|----|-----------|------|
| 1  | Profit    | Rp   |
| 2  | Demand    | Kg   |
| 3  | Price     | Rp   |

Table 3. Description of input parameters for the third FIS.

| No | Parameter     | Unit  |
|----|---------------|-------|
| 1  | Rainfall      | mmHg  |
| 2  | Land Area     | M²    |
| 3  | Irrigation    | lt/seconds/Ha |

Table 4. Description of input parameters for the fourth FIS.

| No | Parameter           | Unit        |
|----|---------------------|-------------|
| 1  | Villager Potential  | Range (0-10)|
| 2  | Land Potential      | Range (0-10)|
| 3  | Market Potential    | Range (0-10)|

Every process of FIS has the input parameters, the fuzzy inference system, a set of rules. The dependence diagram of fuzzy expert system for predicting commodity potential is presented in figure 3.
4. **Result and Discussion**

4.1. **Knowledge Representation**

After obtaining knowledge from various sources, then the representation technique is used to develop expert systems. The development of this expert system uses production rules to present procedural knowledge representation. The form of production rules used are if-then forms. "If" is a premise that shows a condition that will be assessed and "then" is a conclusion that shows actions that can be taken if conditions are met. The complete rules obtained are 145 rules consisting of 64 of the first FIS, and 27 rules for the second, third and fourth FIS respectively. An example of rules for the first FIS:

IF (Man = Man) AND (Age = Nature) AND (Ilness = Low) AND (Quality of Education = High) THEN (Villager Potential = Very Potential).

An example of rules for the second FIS:

IF (Profit = High) AND (Demand = High) AND (Price = Middle) THEN (Market Potential = Very Potential).

An example of rules for the third FIS:

IF (Rainfall = Middle) AND (Land Are = Middle) AND (Irrigation = Middle) THEN (Land Potential = Potential).

4.2. **Development of Inference Engine**

An intelligent system for determining superior commodities using the Mamdani model. For defuzzification using a center of gravity, as in the figure 4.
Figure 4. Defuzzification using the Center of Gravity (CoG) method [12].

The first FIS is developed for producing the output of potential of citizens which is the important factor in determining commodity potential. The fuzzification of this FIS involves four parameters of fuzzy input and one parameter of fuzzy output. Fuzzy classification, range and domain of the input and output parameter of the first FIS is presented in table 5.

| Function    | Variable       | Category | Range   | Domain   |
|-------------|----------------|----------|---------|----------|
| Age         | Young          | [0 - 75] | [0 10 20] |
|             | Nature         | [0 - 75] | [10 35 60] |
|             | Old            | [50 65 75] |
| Quality of  | Low            | [0 - 500] | [0 100 200] |
| Education   | Middle         | [0 - 500] | [125 250 375] |
|             | High           | [0 - 500] | [300 400 500] |
| Man         | Low            | [0 - 500] | [0 100 200] |
|             | Middle         | [0 - 500] | [125 250 375] |
|             | High           | [0 - 500] | [300 400 500] |
| Illness     | Low            | [5.5 - 8.5] | [5.5 5.8 6.5] |
|             | Middle         | [5.5 - 8.5] | [5.8 7 8.2] |
|             | High           | [5.5 - 8.5] | [7.5 8.2 8.5] |
| Potential   | Not Potential  | [0 - 10] | [0 4] |
| of Citizens | Potential      | [0 - 10] | [2 5 8] |
|             | Very Potential | [0 - 10] | [6 10] |

The second FIS is developed for producing the output of market potential which is the important factor in determining commodity potential. The fuzzification of this FIS involves three parameters of fuzzy input and one parameter of fuzzy output. Fuzzy classification, range and domain of the input and output parameter of the second FIS is presented in table 6.
Table 6. Fuzzy classification and domain of the second FIS.

| Function | Variable | Category | Range           | Domain     |
|----------|----------|----------|-----------------|------------|
| Profit   | Profit   | Low      | [0 - 1500]      | [0 300 600]|
|          |          |         |                 | [400 750 1000] |
|          |          | Middle   | [0 - 1500]      | [850 1250] |
|          |          | High     | [0 - 1500]      | 1500       |
| Demand   | Demand   | Low      | [0 - 1000]      | [0 250 600]|
|          |          | Middle   | [0 - 1000]      | [300 625 800] |
|          |          | High     | [0 - 1000]      | 1000       |
| Input    | Price    | Low      | [0 - 5000]      | [0 1250 2000] |
|          |          | Middle   | [0 - 5000]      | [1500 3250 3750] |
|          |          | High     | [0 - 5000]      | 3000 4200 5000 |
|          | Market Potential | Not Potential | [0 - 10] | [0 4] |
|          | Output   | Potential | [0 - 10] | [2 5 8] |
|          |          | Very Potential | [0 - 10] | [6 10] |

The third FIS is developed for producing the output of land potential which is the important factor in determining commodity potential. The fuzzification of this FIS involves three parameters of fuzzy input and one parameter of fuzzy output. Fuzzy classification, range and domain of the input and output parameter of the second FIS is presented in table 7.

Table 7. Fuzzy classification and domain of the third FIS.

| Function | Variable | Category | Range          | Domain     |
|----------|----------|----------|----------------|------------|
| Rainfall | Rainfall | Low      | [0 - 450]      | [0 150]    |
|          |          |         |                | [100 225 350] |
|          |          | Middle   | [0 - 450]      | [300 450]  |
|          |          | High     | [0 - 450]      | [450 750 1100] |
| Land Area| Land Area| Low      | [0 - 1500]     | [0 600]    |
|          |          |         |                | [450 750 1100] |
|          |          | Middle   | [0 - 1500]     | [900 1500] |
|          |          | High     | [0 - 1500]     | [0 0.6]    |
| Irrigation| Irrigation| Low      | [0 - 2]        | [0.4 1 1.6]|
|          |          |         |                | [1.4 2]    |
|          |          | Middle   | [0 - 2]        | [0.4 1 1.6]|
|          |          | High     | [0 - 2]        | [1.4 2]    |
The fourth FIS is developed to produce the final output namely the commodity potential. The fuzzification of this FIS involves three parameters of fuzzy input coming from the output of first, second and third FIS and one parameter of fuzzy output. Fuzzy classification, range and domain of the input and output parameter of the third FIS is presented in table 8.

### Table 8. Fuzzy classification and domain of the final FIS.

| Function           | Variable          | Category          | Range    | Domain       |
|--------------------|-------------------|-------------------|----------|--------------|
| Output             | Land Potential    | Not Potential     | [0 - 10] | [0 4]        |
|                    |                   | Potential         |          | [2 5 8]      |
|                    |                   | Very Potential    |          | [6 10]       |

Following one of the membership function of input and output in the form of a formula:

Membership Function of each fuzzy set of villager potential parameter is as follows:

\[
\mu_{\text{Not Potential}}(x) = \begin{cases} 
0, & x \geq 4 \\
1, & x = 0 \\
\frac{4-x}{4}, & 0 < x < 4 
\end{cases}
\] (3)

\[
\mu_{\text{Potential}}(x) = \begin{cases} 
0, & x \leq 2 \text{ or } x \geq 8 \\
\frac{(x-2)}{(5-2)}, & 2 < x < 5 \\
1, & x = 5 \\
\frac{(8-x)}{(8-5)}, & 5 < x < 8 
\end{cases}
\] (4)

\[
\mu_{\text{Very Potential}}(x) = \begin{cases} 
0, & x \leq 6 \\
1, & x = 10 \\
\frac{(x-6)}{(10-6)}, & 6 < x < 10 
\end{cases}
\] (5)
Membership Function of each fuzzy set of market potential parameter is as follows:

\[
\mu_{Not\ Potential} (x) = \begin{cases} 
0, & x \geq 4 \\
1, & x = 0 \\
(4-x)/(4-0), & 0 < x < 4 
\end{cases}
\] (6)

\[
\mu_{Potential} (x) = \begin{cases} 
0, & x \leq 2 \text{ or } x \geq 8 \\
(x-2)/(5-2), & 2 < x < 5 \\
1, & x = 5 \\
(8-x)/(8-5), & 5 < x < 8 
\end{cases}
\] (7)

\[
\mu_{Very\ Potential} (x) = \begin{cases} 
0, & x \leq 6 \\
1, & x = 10 \\
(x-6)/(10-6), & 6 < x < 10 
\end{cases}
\] (8)

Membership Function of each fuzzy set of land potential parameter is as follows:

\[
\mu_{Not\ Potential} (x) = \begin{cases} 
0, & x \geq 4 \\
1, & x = 0 \\
(4-x)/(4-0), & 0 < x < 4 
\end{cases}
\] (9)

\[
\mu_{Potential} (x) = \begin{cases} 
0, & x \leq 2 \text{ or } x \geq 8 \\
(x-2)/(5-2), & 2 < x < 5 \\
1, & x = 5 \\
(8-x)/(8-5), & 5 < x < 8 
\end{cases}
\] (10)

\[
\mu_{Very\ Potential} (x) = \begin{cases} 
0, & x \leq 6 \\
1, & x = 10 \\
(x-6)/(10-6), & 6 < x < 10 
\end{cases}
\] (11)

5. Conclusions and Suggestions

Based on the discussion that has been discussed, some conclusions can be drawn. The input variables used in this study are 10. For the potential of the land and market potential, each of the 27 rules and for the potential of the citizens to produce 64 rules. In the next FIS process, it produces 27 rules to get a potential commodity, so the total rules obtained are 145 rules. Input parameters and rules are obtained based on data, interviews with villagers (practical experts), and related journals and textbooks. Hopes that with this intelligent system, in making the Village RPJM, the village government can be more focused on developing superior commodities in the Sukadamai village. With the development of preferred commodities in the Sukadamai village, can help improve the quality of life of Sukadamai villagers.

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