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Comparison Analysis of Fuzzy Mamdani and Sugeno Methods for the Detection of Flooded Vulnerable Areas: A Case Study of Pringsewu Sub-district

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Abstract:

Vulnerability is a situation or condition that can reduce the ability of communities to prepare themselves for hazards or disaster threats. The purpose of knowing vulnerability is to reduce the negative impacts caused by disaster. So, the problem formulation in this research is about the comparison between fuzzy mamdani method with fuzzy sugeno method to detect flood prone area in Pringsewu Sub-district. The prototype that can determine flood prone areas, is still on construction in Pringsewu Sub-district. This prototype can reduce flood risk both through physical development as well as awareness and capacity building for disaster. This research yields the conclusion that is safe, vulnerable and flood. For the calculation begins by specifying the fuzzy set of each variable, the formation of fuzzy rules (implications), the composition of rules using MAX function, and also affirmation (defuzzification). While the prototype begins using Graphic User Interface, then complete the code on the Matlab R2013a software so the vulnerability detection design can work well. After the prototype of flood vulnerability detection was successfully made, the monographic data of Pringsewu Sub-district could be input into the prototype. Next will be processes using the Fuzzy Inference System method that has been entered into the prototype, then the result will appear. At the end of Mamdani method, it has 70% accuracy value while Sugeno method has 48.33% accuracy value. So from this result, we know that Mamdani method has better accuracy than Sugeno method.

Keywords -***Disaster, Flood, Fuzzy mamdani, Fuzzy Sugeno, Matlab, Graphic User Interface***

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1. INTRODUCTION

As a new district, Pringsewu Sub-district is experiencing rapid development and establishment every year. Like other big cities, as a result of the development of green open space becomes reduced, due to the transfer of land to support the smoothness of economic activities and activities in the Pringsewu sub-district. So many lands are covered by roads and buildings, so that water absorption areas in the soil become reduced. As a result, floods in Pringsewu District often occur. The largest flood case in Pringsewu District occurred in 2010 there are 38 cases of floods, it needs to do disaster mitigation. Mitigation is a series of efforts to reduce disaster risks, both through physical development, awareness and increased capacity to deal with disaster threats (Law No.24 Article 1 No. 06 Year 2007- [8]). Problems that exist in

Pringsewu District especially in District Pringsewu, detection process of flood prone area at Pringsewu Sub-district during this time after flood disaster. One of the efforts as disasters mitigation, needs to be done pre-disaster detection through approach with fuzzy research methodology Mamdani and Sugeno. This study conducted a comparison of two methods of fuzzy namely, fuzzy Mamdani and Sugeno method using monograph data in Pringsewu District that is population density, river drainage, slope territory, altitude and rainfall. This research will produce prototype detection of flood vulnerable area built using Matlab R2013a software based on fuzzy inference system, prototype built from comparative analysis method of Fuzzy Mamdani and Sugeno, which apply Mamdani fuzzy method with best accuracy value.

2. THEORICTAL BASIS

2.1 Definition of Disaster

Based on RI Law Number 24 Year 2007 on Disaster Mitigation that disaster is an event or series of events that interfere with people's lives and livelihoods, caused by natural and non-natural factors and human factors resulting in the occurrence of human lives, environmental damage and property loss psychological impact.

2.2 Definition of Flood

Floods are higher than normal water levels in rivers and usually flow overflowing over river banks and overflow means to pool in a puddlearea (Hadisusanto, 2011: 19-[12]). Flooding becomes a problem and develops into a disaster when the flood disrupts human activity and even carries casualties and property (Sobirin, 2009: 9-[9]).

2.3 Definition of Fuzzy Logic

Fuzzy logic is one of the composers of soft computing. Fuzzy logic was first introduced by prof. Lotfi A. Zadeh in 1965. The basis of fuzzy logic is the theory of the fuzzy set. In the fuzzy set theory, the role of membership degree as the determinant of the existence of elements in a set is very important. The membership value or membership degree or membership function is the main characteristic of reasoning with the fuzzy logic.

2.4 The Fuzzy Mamdani Method Inference System

Mamdani method is often also known as min-max method. This method was introduced by EbrahimMamdani in 1975. To get the output required 4 stages, namely:

1. Formation of fuzzy set In Mamdani method both input and output variables are divided into one or more fuzzy sets.
2. Application of implication function In Mamdani Method, implication function used is min.
3. Rule Composition The method used in conducting fuzzy system inference, the method max (maximum). In general it can be written:
   µsf [Xi] = max (µsf [Xi], µkf [Xi]) By: µsf [Xi] = fuzzy membership solution value until rule to iµkf [Xi]) = value of fuzzy membership rulei
4. Defuzzy(Defuzzification) on the composition of Mamdani rules using the centroid method. Where in this method, the crisp solution is obtained by taking the fuzzy area center point. Generally formulated:

$$\boldsymbol{z^* = \frac{\int_z z\mu(z)dz}{\int_z \mu(z)dz}}$$

$$\boldsymbol{z^* = \frac{\sum_{j=1}^{n} zj\mu\,(zj)}{\sum_{j=1}^{n} \mu(zj)}}$$

2.5 Fuzzy Sugeno Method of Fuel System

Fuzzy Sugeno logic is almost the same as Mamdani method, only the output (consequently) system is not a fuzzy set but a linear constant / equation. This method was developed by Takagi Sugeno Kang in 1985. TSK (Sugeno) method consists of 2 types, namely:

1. Fuzzy Sugeno Method Zero Order

In general, this model is:
IF (X1is A1) o. (X2is A2) o. (X3 is A3) o. . . O (XnisAn) THEN z = k
With:
A1 is the set of i-fuzzy as an antecedent
K are constants (consequent) as consequent

2. The Sugeno Fuzzy Method of Order One
In general, the form of this model is:
IF (X1is A1) o. . . O (XnisAn) THEN z = p1 * x1 +. . . + Pn * xn + q
With:
A1 is the set of i-fuzzy as an antecedent
P1 is the i-th (i) constant
Q are constants in consequence
If we use Fuzzy Sugeno Logic, then deffuzification is done by finding the average value.

2.6 Study Overview

There are several studies that apply fuzzy methods such as: Research conducted by Arief L.N. Purnama B.S. And Trias Aditya on flood disaster risk mapping Rob Semarang. Based on this research process, vulnerability modeling can be approached using fuzzy logic mamdani method which gives good result in robotic flood risk assessment process in Semarang (Arief L.N.2012- [2]). Research conducted by RabiatulAdawiah and Ruliah conduct research of decision support system of selection of scholarship acceptance at STMIK Banjar Baru campus Banjarmasin. Research conducted by the author that compares the results of the calculation of Fuzzy Mamdani with AHP. After seeing the results of the calculation, Fuzzy Mamdani get the result that is equal to 85.7% while the AHP calculation is 14.3%. Viewed on the calculation result, Fuzzy Mamdani method can be used for selection of majors. (RabiatulAdawiyah and Ruliah.2013- [1]).

3. METHODOLOGY AND RESEARCH DESIGN

3.1 Sample Selection

Population of data that used in this research is Pringsewu District monograph data include population density, river drainage, slope territory, altitude and rainfall. The data will be used as parameters to determine flood prone areas in Pringsewu District.

3.2 Data Collection

Data collection methods used in this study is documentation, written sources based on existing documents in the district office Pringsewu, literature study by studying, researching and reading books, journals, thesis, thesis related to research methodology, and also observation. Observation made by observing directly systematically to the symptoms or phenomena that occur in the field. It aims to know the areas that often occurs flood. Interview, resulted in the form of flood characteristic data which was done by direct question and answer with informant.

3.3 Analysis and Testing Techniques

The research will be conducted using the fuzzy methods of Mamdani and Sugeno. The methods will be used to process the monument data of Pringsewu Sub-district in the form of density of population, drainage of river flow, slope area, altitude and rainfall. The result of data processing will get the set of fuzzy input and output flood vulnerable area. The fuzzy methods of Mamdani and Sugeno will be compared to get the best method to be applied in the design of the system prototype.

3.4 Research Steps

The steps taken in this study:

Figure III.1 Research Steps

4. RESULTS AND DISCUSSION

4.1 Composition of Mamdani Rules

The composition of the rule of the implication function using MAX is by taking the maximum value from the rule output. If all propositions have been evaluated, the output will contain fuzzy sets that reflect the contribution of each proposition. The composition of the rules for the previous sample is:

Max method is used to determine the composition of rules.

Output variables:

Degree of truth of the Vulnerable set

= Max (α497; α521; α533)
= Max (0,333; 0,25; 0,25)
= 0,333

The degree of truth of the Flood set

= Max (α485; α486; α498; α522; α534)
= Max (0,667; 0,3; 0,3; 0,25; 0,25)
= 0,667

Based on the membership function of the variable set of vulnerable sets at the time of α497

Obtained value of 0.33 d (497) as follows

$$\mu_R(d497) = \alpha497 \iff \frac{d(497)-10}{20-10} = 0{,}333$$

d(497) – 10 = 3,333

d(497) = 13,333

$$\mu_R(d497) = \alpha497 \iff \frac{d(497)-40}{50-40} = 0{,}333$$

d(497) – 40 = 3,333

d(497) = 43,333

Based on the membership function of the variable set of vulnerable sets at the time of α485

Obtained value of 0.667 d (485) as follows:

$$\mu_R(d485) = \alpha485 \iff \frac{d(485)-40}{50-40} = 0{,}667$$

d(485) – 40 = 6,667

d(485) = 46,667

Modification The high membership function of the output variable after applied αcut is:

$$\mu(x) = \begin{cases} (0{,}1x-1); & 10 \le d_{497} \le 13{,}33 \\ 0{,}333; & 13{,}33 < d_{497} \le 43{,}33 \\ (0{,}1x-4); & 43{,}33 < d_{497}, d_{485} \le 46{,}67 \\ 0{,}667; & 46{,}67 < d_{485} \le 100 \end{cases}$$

4.2 Defuzzification

At the defuzzification stage, there is a difference between Fuzzy Mamdani and Fuzzy Sugeno. For Fuzzy Mamdani, the defuzzification process is done by cetroid method:

$$Z^* = \frac{\int_z z\mu(z)dz}{\int_z \mu(z)dz}$$

$$Z^* = \frac{M_1+M_2+M_3+M_4}{L_1+L_2+L_3+L_4}$$

$$M_1 = \int_{10}^{13{,}33} (0{,}1.x-1).x\,dx = 6{,}32$$

$$M_2 = \int_{13{,}33}^{43{,}33} (0{,}333.x)dx = 283{,}0167$$

$$M_3 = \int_{43{,}33}^{46{,}67} (0{,}1.x-4).x\,dx = 68{,}69$$

$$M_4 = \int_{46{,}67}^{100} (0{,}667.x\,dx = 2605{,}34$$

$$L_1 = \int_{10}^{13,33} (0{,}1.x - 1)\, dx = 0{,}33$$

$$L_2 = \int_{13,33}^{43,33} (0{,}33\, dx = 9{,}99$$

$$L_3 = \int_{43,33}^{46,67} (0{,}1.x - 4)\, dx = 68{,}69$$

$$L_4 = \int_{46,67}^{100} (0{,}667\, dx = 35{,}37$$

The crisp output value is calculated by:

$$Z^* = \frac{6{,}32+283{,}0617+68{,}69+2605{,}34}{0{,}03+9{,}99+68{,}69+35{,}37}$$

$$= \frac{2963{,}367}{47{,}78}$$

$$= 62{,}02$$

The output value limit is:
1. "SAFE" assessment: output value limit <15
2. "VULNERABLE" Rating: output value limit 15 ≤ x ≤ 45
3. "Flood" Rating: output value limit> 45

So it concluded with existing data and after analyzed, the data used as samples categorized give assessment of flood vulnerable areas with a value of 62.02.

As for fuzzy Sugeno, defuzzification calculation process is done by the formula:

$$Z = \frac{\sum_{i=1}^{n} WiZi}{\sum_{i=1}^{n} Wi}$$

Where :

Wi is the result of fuzzy logic antecedent operation process

Zi is the output of rule 1

Z =

$$\frac{(0,667x70) + (0,3x70) + (0,333x45) + (0,3x70) + (0,25x45) + (0,25x70) + (0,25x45) + (0,25x70)}{0,667 + 0,3 + 0,333 + 0,3 + 0,25 + 0,25 + 0,25 + 0,25}$$

$$= \frac{161{,}175}{2{,}60}$$

= 61,99038

So it concluded with the existing data and after analyzed, the data used as samples categorized to provide assessment of flood vulnerable areas with a value of 61.99038.

4.3 GUI Testing

The GUI test was created using the Matlab R2013a program. The picture below is the main form of the system that has been created in determining flood-prone areas in Pringsewu Sub-district

Figure III.2 Prototype of Flood Vulnerable Area Assessment

1. Mamdani results if in matlab script

```
>>fis=readfis('PswuMamdani.fis')
        fis =
                name: 'PswuMamdani'
                type: 'mamdani'
        andMethod: 'min'
        orMethod: 'max'

        defuzzMethod: 'centroid'

        impMethod: 'min'
```

```
        aggMethod: 'max'
                  input: [1x5 struct]
                 output: [1x1 struct]
                   rule: [1x720 struct]
>> out=evalfis([430 1425 10 12 25],fis)
        out = 30
```

2. Sugeno results if in matlab script

```
>>fis=readfis('PswuSugeno.fis')
        fis =
                name: 'PswuSugeno'
                 type: 'sugeno'
        andMethod: 'prod'
        orMethod: 'probor'
        defuzzMethod: 'wtaver'
        impMethod: 'prod'
        aggMethod: 'sum'
                  input: [1x5 struct]
                 output: [1x1 struct]
                   rule: [1x720 struct]
>> out=evalfis([430 1425 10 12 25],fis)
        out =45
```

4.4 Comparison and Validation of Fuzzy Mamdani and Sugeno Methods

After the calculation of data samples as much as 60 times the experiment, it will be comparation between Mamdani method and Sugeno method with original data from the research object as a reference. After the comparation will be seen the accuracy of the results as follows:

Table III.1 Table Comparison and Validation of Fuzzy Mamdani and Sugeno Methods

No	Performance Assessment		Original Data
	Mamdani	Sugeno	
1	72.6757	70	Flood
2	72.6757	70	Flood
3	72.6757	70	Flood
4	72.6757	70	Flood
5	72.6757	70	Susceptible
6	71.8924	70	Flood
7	65.2298	63.75	Susceptible
8	72.6757	70	Susceptible
9	30	45	Safe
10	30	45	Safe
11	71.8924	70	Safe
12	65.2298	70	Flood
13	72.6757	70	Flood
14	56.4889	54.375	Susceptible
15	72.6757	70	Susceptible
16	72.6757	70	Flood
17	56.4889	70	Flood
18	72.6757	70	Flood
19	72.6757	70	Flood

20	30	45	Susceptible
21	60	65.8333	Flood
22	30	45	Susceptible
23	30	45	Susceptible
24	27.3443	37.5	Safe
25	23.5208	30	Safe
26	30	45	Safe
27	72.6757	70	Flood
28	72.6757	70	Flood
29	30	45	Susceptible
30	30	45	Susceptible
31	72.6757	70	Flood
32	72.6757	70	Flood
33	72.6757	70	Flood
34	72.6757	70	Flood
35	30	45	Susceptible
36	62.4969	61.6667	Flood
37	30	45	Susceptible
38	30	45	Susceptible
39	8.00797	15	Safe
40	7.90909	15	Safe
41	30	45	Safe
42	66.7891	65	Flood
43	72.6757	70	Flood
44	30	45	Susceptible
45	30	45	Susceptible
46	72.6757	70	Flood
47	72.6757	70	Flood
48	30	45	Flood
49	30	45	Flood
50	30	45	Susceptible
51	30	45	Flood
52	30	45	Susceptible
53	30	45	Susceptible
54	8.00797	15	Safe
55	7.90909	15	Safe
56	30	45	Safe
57	30	45	Flood
58	30	45	Flood
59	26.4548	37.5	Susceptible
60	30	45	Susceptible

4.5 Results Accuracy

Understanding accuracy is how close a number of measurements to numbers or actual data. So, the accuracy referred to in this study is the number of measurement results, namely the value of the method Mamdani and Sugeno method that shows the results of the correct output based on data derived from the object of research. If the output value of the fuzzy Mamdani and fuzzy Sugeno calculations is less than 15, then the area is declared "SAFE" or notified as follows: x <15 = "SAFE". If the output value of the fuzzy Mamdani and Sugeno fuzzy is greater than 15 and less than 45, then the area is declared "SUSCEPTIBLE" or notified as follows: 15 ≤ x ≤ 45 = "SUSCEPTIBLE". If the output value of the fuzzy Mamdani and Sugeno fuzzy calculations is greater than 45, then the area is declared "FLOOD" or notified as follows: x ≥ 45 = "FLOOD".

Based on the result of table III.1, it can be seen the fuzzification value between Mamdani method and Sugeno method which has same category with original data, so the result of the comparison is:

1. The Mamdani method produces a total accuracy rate of 70% of 60 experiments

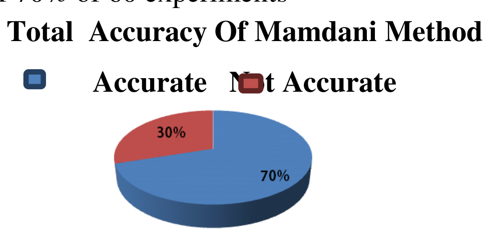

Figure III.3 Graph of Total Accuracy Mamdani Method

2. As for the method Sugeno produce a total accuracy of 48.33% of 60 experiments

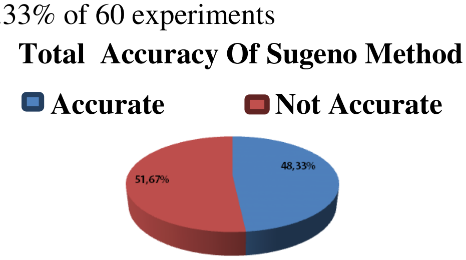

Figure III.4 Graph of Total Accuracy Sugeno Method

So from the test results, showed that Mamdani method better accuracy compared with Sugeno method.

5. CONCLUSION

The result of detection of flood prone area in Pringsewu Sub-district use comparison of two methods, that is Fuzzy Mamdani and Sugeno method. The following conclusions can be drawn:

Based on the evaluation and validation result, it is found that Mamdani fuzzy method get the highest data accuracy value after validated with original data that is 70%, while Sugeno fuzzy method get 48% value. So the fuzzy mamdani method is better than Sugeno, and can be used in detecting flood prone areas in Pringsewu District.

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