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FORECASTING THE NUMBER OF DENGUE FEVER CASES IN MALANG REGENCY INDONESIA USING FUZZY INFERENCE SYSTEM MODELS

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ABSTRACT

Dengue fever is a communicable disease that has been a big concern in Indonesia. This disease has spread out across Indonesia, including Malang Regency. Local Government and Public Health Service in Malang Regency has made various efforts including prevention and socialization, however the number of casualties caused by dengue fever are still high. Forecasting the number of dengue fever cases is very important for the local Public Health Service. It can help policy planning of disease prevention and patient care in the future. Delays in preventive measures, increasing casualties, lack of treatment facilities are the problems that can be avoided through better policy planning. In this research, Fuzzy Inference System (FIS) is used to predict number of dengue fever cases in Malang. FIS tends to have small error values and high accuracy due to detailed attention to all variables. Fuzzy Inference System does not require a lot of data and a long periods of time. The model is constructed by grouping the number of monthly dengue fever cases from the previous years based on geographical location. Population density is added as external variables of the model. The data is divided into training set, testing set, and validating set with the ratio of 70:20:10. This research shows that forecasting model based on FIS shows a good results in forecasting with MAPE 6% in lowlands, 12% in mediumlands, and 14% in highlands.

Keywords: *Forecasting, Fuzzy Inference System, Dengue Fever, Disease, MAPE*

1. INTRODUCTION

Dengue fever has become a major health problem in Indonesia. The number of cases and spreading of this deadly disease increase is in line with the increasing of mobility and population density. The total population of Indonesia is more than 250 million people, making it the 4th biggest population in the world[1]. According to WHO, number of dengue fever cases in Indonesia is the highest in Southeast Asia[2][3].

Based on current conditions, the government has taken some measures to decrease the number of Dengue Fever cases. A local regulation number 2 in 2011 is implemented. It explains about controlling of dengue fever in Malang [4]. The success of this controlling action is measured by *Angka Bebas Jentik*/number of mosquito larva exists (ABJ) and *Angka Kematian*/death due to dengue fever (AK) [2]. Despite of all the efforts, these actions haven't show an optimal results yet.

The increasing number of casualties and patients show that the authorities are not prepared with the precautions needed. Public Health Service needs a report on the number of dengue fever cases in a certain area before deciding to do fogging [5]. Due to these conditions, a quantitative model that describes the dynamics of dengue fever cases number is needed. Models with sufficient accuracy can be used as a tool for decision-making and the distribution of resources to address the epidemic [6][7].

Research about dengue fever number forecasting has been done before in Thailand [8] and Colombia [9]. In Thailand, forecasting model is generated through ARIMA univariate method. Other factors that may have significant impact to dengue cases transmissions is not considered. In Columbia, a research about the number of dengue fever forecasting was done by fuzzy approach. It used two variables, they are the number of Dengue Fever cases were relatively mild and were considered

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severe. Forecasting models was made show that fuzzy approach can produce accurate predictions [8][9].

There have been several researches conducted to explore the using of Fuzzy. Edangogade [10] applied Fuzzy in hydro_environment field and found that fuzzy approach good enough for the data history and more profitable than other statistical methods and artificial neural network. Tomasz [11] using fuzzy approach in the economics field and indicated that the fuzzy logic models has high practical value. Amrita et.al [12] applied fuzzy approach in transportation field. The results showed that the fuzzy logic approach could be used successfully to situations model in which people of make a complex decisions [12].

Based on the advantages of fuzzy methods that have been mentioned previously, in this study, fuzzy was used to forecast the number of dengue fever patients in the district of Malang, Indonesia. Forecasting the number of dengue fever patients involves the effect of population density variable that has never been done before.

The main contribution of this paper are the following:

1. We propose Fuzzy models to forecast the number of Dengue Fever cases in Malang Indonesia which involves the population density variable.
2. These models were grouped into three districts groups based on geographical location. The district groups are lowlands, mediumlands, and highlands. The aim of this grouping is to see how the geographical location affects the dynamics of dengue fever cases.

Public Health Service in Malang can use these forecasting model as an early detection of an increase of Dengue Fever cases. The result of forecasting can support demand planning of health services, medical personnel, as well as drugs that are needed in the future [13] [14].

2. MALANG REGENCY CONDITION

Malang regency is the second largest area in East Java. This is evidenced by the area of Malang regency reached 3534.86 km2 or 383 486 ha. East Java consist of 38 regencies and cities in East Java. In 2010, total population reached 2,446,218. With the diversity of geographical conditions that are owned by the regency of Malang, makes this region has great tourism potential enough. That area is located in some of the slopes of the mountain, the beach, and the sea. However, these conditions make the dengue fever mosquito grows and develops rapidly. Malang regency was reportedly become the highest dengue endemic area in East Java. Therefore, it need an action to prevent the effects that can be caused by the mosquito development. Based on this geographic conditions, this research area classifies the area into three groups, namely lowlands, mediumlands, and highlands.

Monthly data of dengue fever cases ranging from 2009 to 2014 are used. This data is obtained from Public Health Services Malang. There are 39 districts in malang. It will be grouped into three groups based on geographical location: low lands, medium lands, and high lands. Population density is used as independent variables.

The number of dengue fever patients in recent years and the population density are shown in Figure 1 and Figure 2.

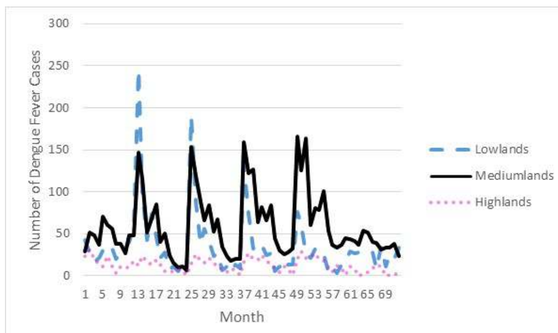

Figure 1 : Plot of Number of Dengue Fever Cases

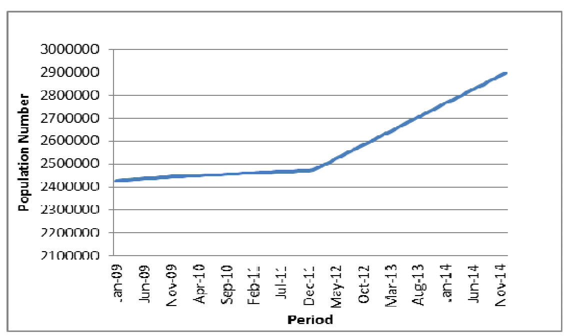

Figure 2 : Plot of Population Density

3. RESEARCH METHODOLOGY

3.1 Data Preprocessing

Data preprocessing is done to ensure there is no missing value and no outliers of data in this series. The missing values of the data are handled by

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interpolation technique [15].

In forecasting, the type of data must be the same, for example annual, monthly, or daily. The period of data which used must equal too. Because of the population data consist of 2009-2013 only, it necessary to extend the data in order to have the period until 2015. Extend data was done by a double exponential smoothing method. It was adapted with population data pattern that's usually has a trend pattern.

3.2 Implementation of Fuzzy

3.2.1 Fuzzyfication

In this process, the input variables that are still crisp are transformed into a fuzzy sets value [16]. This set is divided by the number of cases, namely Very Very Low (VVL), Very Low (VL), Low (L), Normal (N), High (H), Very High (VH), Very Very High (VVH). Domain of the set will be adjusted to the universe of discourse of each variable. The variables of number of Dengue Fever cases and population density have a linear relationship. They were also affected by the time. Furthermore, the membership function of each variable will be created and represented by the curve down (for the Low fuzzy set), linear curve rises (for the High fuzzy set) and triangular curve (for the Normal fuzzy set). This function is the result of a fuzzyfication process.

3.2.2 Basic rules development

In this process fuzzy rules are built on each pair of input and output variables. This pairs will generate rules in the form of "IF...THEN..." implications [17]. Furthermore, the membership degree of each rule will be calculated using frbs package in R. The rule will be selected to produce the basic rules of fuzzy.

3.2.3 Inference

This implication process using the input values from fuzzification process result which was used in Max-Min operation. Methods used in performing fuzzy inference system are [17]:

- Max Method (Maximum)

  This method takes the maximum value of the fuzzy set. This value use to modify the fuzzy area, and apply it to get an output value use OR operator (union). If all propositions have been evaluated then the output will contain a fuzzy set which reflect the contribution of each proposition.

- Additive method (Sum)

  This method performs bounded-sum of all output fuzzy region to obtain fuzzy set solutions.

- Probabilistic OR Methods (Probor)

  This method performs the product of all output fuzzy region to obtain fuzzy set solutions.

3.2.4 Defuzzyfication

In this process, fuzzy sets variables is converted into crisp set. We use a Centroid method (Composite Moment). The Centroid method generally formulated [18][19]:

$$z^* = \frac{\int_z z\mu(z)dz}{\int_z z\mu(z)dz} \qquad (1)$$

where
z : output variable
z* : a central point of output area
μ(z): output variable membership function

3.3 Model Testing and Validation

There are three testing scenarios, namely: experiment of membership function representation are symmetric, like a data pattern, and linier curve. In this step, we will be determine the best models for forecasting. In model validation, the best model will be validated using data testing. Validation results will show that the model can be used to perform the prediction for another data. The result is good enough if the Mean Absolute Percentage Error (MAPE) lower than 20% [20]. MAPE is defined below [20][21][22]:

$$MAPE = \frac{\sum_{t=1}^{n} \left| \frac{xt - ft}{xt} \right|}{n} \; x\ 100\% \qquad (2)$$

where
n: number of data
x_t: data actual at t period
f_t: data forecast at t period.

3.4 Forecasting and Analysis

The next step is to forecast the number of dengue fever cases over the next period using the best model for both trainset and testset. The forecasting result will be analyzed. The analysis

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result will be used as consideration factor for Public Health Service in order to make a decision related to preventive measures of dengue fever.

4. RESULTS AND DISCUSSION

4.1 Fuzzy and Defuzzyfication Modeling

Three different forecasting models will be generated for each district groups. Table 1 shows a list of variables used in making the model.

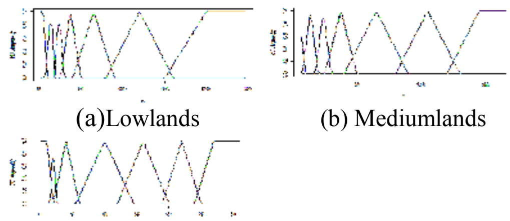
Table 1: Variable List And Description

Variables Name	Description
Lowlands dengue cases	Number of dengue cases in the lowlands district group. Monthly data
Mediumlands dengue cases	Number of dengue cases in the mediumlands district group. Monthly data
Highlands dengue cases	Number of dengue cases in the highlands district group. Monthly data
Population Density	The number of people in Malang. This data is extended for each month.
Forecasting of lowlands dengue cases	Forecasting result of dengue cases number in the lowlands district group. Monthly data
Forecasting of mediumlands dengue cases	Forecasting result of dengue cases number in the mediumlands district group. Monthly data
Forecasting of highlands dengue cases	Forecasting result of dengue cases number in the highlands district group. Monthly data.

A fuzzy model is generated based on number of dengue fever cases as dependent variables and population density as an independent variables. There is only one fuzzy set of population density variables, with s-curves as the membership function.

Fuzzy set for forecasting of dengue cases number variable were divided into seven sets, namely: Very Very Low (VVL), Very Low (VL), Low (L), Normal (N), High (H), Very High (VH), Very Very High (VVH).

Dengue cases variable became input variable of the model. This research use the shoulder type for represent the membership functions. It is a combination of trapezoidal and triangular membership function. VVL set has limitations of membership function which was illustrated by blue line in Figure 2. Therefore, VL, L, N, H, and VH sets have limitations of membership functions that represented by the pink line in Figure 2. It indicates the type of triangular representation. VVH set has limitations of membership function which represented by the green line. It indicates the type of a trapezoid representation. The representation of dengue cases variable for each models is shown in Figure 3. Details of the membership function limitations can be seen in Figure 4.



(a)Lowlands (b) Mediumlands (c) Highlands

Figure 3 : 1st Input Model: Number of Dengue Cases in Each Lands

Population density variable also became input variable of the model. This membership function use curve-s type. This curve shows the set of growth. The representation of population density variable for each model is shown in Figure 3 and the details of the membership function limitations can be seen in Figure 4.

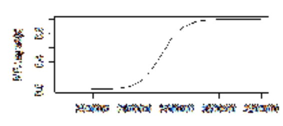


Figure 4 : 2nd Input Model: Population Density

A membership function limitation shows fuzzy set ranges of each input variable of the models. The first row is membership functions type, where 1 shows a triangle type, 2 shows a trapezoid on the left side type, 3 shows a trapezoid on the right side type, and 6 shows a sigmoid type. Second until fifth row show the vertices which use to build membership functions. Membership functions of input variable of each models is shown in Figure 5.

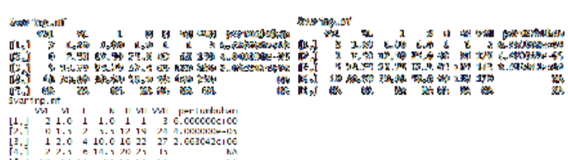


Figure 5 : Membership Function Limitations For Input Variables

Forecasting results of dengue cases variable became output variable of the model. The

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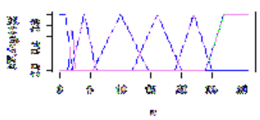
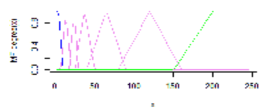
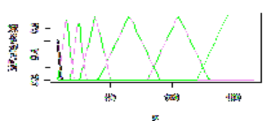
membership functions use the shoulder type which is combination of trapezoidal and triangular type. VVL set has membership function limitations which is illustrated by the blue line on the left side. It indicates the type of a trapezoid shape on the left side representation. VL, L, N, H, and VH sets have limitations of membership functions which are presented by the pink line. It indicates the type of triangular representation. VVH set has membership function limitations which is represented by the green line. It indicates the type of a trapezoid shape on the right side representation. The forecasting results of dengue cases variable representation for each models is shown in Figure 6.



(a) Lowlands



(b) Mediumlands



(c) Highlands

Figure 6 : Output Model: Forecasting Of Each Lands Dengue Cases

Membership function Limitations show the fuzzy set ranges from output variable. The first row is the membership functions type, where 1 shows a triangle type, 2 shows a trapezoid on the left side type, and 3 shows a trapezoid on the right side type. Second until fifth row shows the vertices which use to build membership functions. The membership functions limitations of output variable for each models is shown in Figure 7.

Data range of variables in the model show the universe of discourse of each variable. 1st column is data range of 1st input variable, 2nd column is data range of 2nd input variable, 3rd column is data range of 3rd input variable. The first row shows the smallest value, and the second row shows the biggest value of data. Data Range of variabels model is shown in Figure 8.

```
$varout.mf
     VVL    VL     L    N  H  VH VVH
[1,]   2  1.00  1.00  1.0  1   1   3
[2,]   0  7.50 17.50 25.0 40  80 150
[3,]   5 13.75 23.75 37.5 65 120 200
[4,]  10 20.00 30.00 50.0 90 160 250
[5,]  NA    NA    NA   NA NA  NA  NA
$varout.mf
     VVL    VL     L    N  H  VH VVH
[1,]   2  1.00  1.00  1.0  1   1   3
[2,]   0  7.50 17.50 25.0 40  80 120
[3,]   5 13.75 23.75 37.5 65 105 145
[4,]  10 20.00 30.00 50.0 90 130 170
[5,]  NA    NA    NA   NA NA  NA  NA
$varout.mf
     VVL  VL  L    N  H VH VVH
[1,]   2 1.0  1  1.0  1  1   3
[2,]   0 1.5  2  5.5 12 19  24
[3,]   1 2.0  4 10.0 16 22  27
[4,]   2 2.5  6 14.5 20 25  35
[5,]  NA  NA NA   NA NA NA  NA
```

Figure 7 : Membership Function Limitations Of Output Variables

```
$range.data.ori
     [,1]    [,2] [,3]
[1,]    3 2428283    3
[2,]  246 2897800  246
$range.data.ori
     [,1]    [,2] [,3]
[1,]    7 2428283    7
[2,]  166 2897800  166
$range.data.ori
     [,1]    [,2] [,3]
[1,]    0 2428283    0
[2,]   31 2897800   31
```

Figure 8 : Data Range of Variables Model

Fuzzy rules which applied to all models in this research are shown in Table 2.

Table 2: List Of Fuzzy Rules

No	*Fuzzy Rules*
1.	"IF" "input1" "is" "VVL" "and" "input2" "is" "growth " "THEN" "output1" "is" "VVL"
2.	"IF" "input1" "is" "VL" "and" "input2" "is" "growth " "THEN" "output1" "is" "VL"
3.	"IF" "input1" "is" "L" "and" "input2" "is" " growth " "THEN" "output1" "is" "L"
4.	"IF" "input1" "is" "N" "and" "input2" "is" " growth " "THEN" "output1" "is" "N"
5.	"IF" "input1" "is" "H" "and" "input2" "is" " growth " "THEN" "output1" "is" "H"
6.	"IF" "input1" "is" "VH" "and" "input2" "is" " growth " "THEN" "output1" "is" "VH"
7.	"IF" "input1" "is" "VVH" "and" "input2" "is" " growth " "THEN" "output1" "is" "VVH"

4.2 Model Validation

The model is said to be fit if it has a certain level of validity. The different data sets were provided to determine the validity of model. The data is devided into training set, testing set, and validating set. The training set is used to find the models. The testing set is used to test the training models and find the best training model. The validating test is used to see whether the best model still valid in making

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forecast of another data. Therefore, the best model use for forecast next periods.

There are three different testing scenarios in this research. This scenarios are used to test the best training model. The first scenario is test on a model where number of dengue fever cases variable has a symmetrical membership function limitation. The second scenario, is test on a model where number of dengue fever cases variable has a membership function limitation as like the pattern of data. The last scenario is test on a model where population density variable has a linear membership function limitation. The MAPE comparison between scenario testing result is shown in Table 3.

Table 3: MAPE Comparison

Scenario	Training Data	Testing Data
1st scenario	38%	38%
2nd scenario	11 %	13%
3rd scenario	14 %	13%

The 2nd scenario has small error value on the training data and testing data, so it is become the best model testing model. It's means that the form of membership function representation have siginificant affect to the forecasting results Cfunction affect the accuracy of the number of dengue fever cases forecasting, where the population density is more suitable use S Curve than the linear curve. This is also supported by trial with the membership function which was generated automatically using certain tools with no known function. It shows that the mape average of its more than 100%.

The best testing model in 2nd scenario need to be validated in order to make sure that it suitable to forecast next periods. The result of validation model process in each group area of Malang District is shown in Table 4.

Table 4: The Results of Validation Model Process

Forecasting Results	MAPE
Lowlands	6%
Mediumlands	12%
Highlands	14%

Based on Table 4, it is shown that the best model in each group of area in Malang has MAPE < 20%. It's means that this models is valid and suitable to forecast the number of dengue fever case in next periods.

In another experiment, to see how the effect of the addition of population density variable on forecasting. This research carried out experiments using the best scenario that has been obtained previously and then omitted the population density variable. MAPE results for this model are shown in Table 5.

Table 5: The MAPE Of Models

Forecasting Results	MAPE With Population Density Variable	MAPE Without Population Density Variable
Lowlands	6%	12%
Mediumlands	12%	24%
Highlands	14%	44%

Table 5 shows that a population number variable has a very significant influence on forecasting the number of Dengue Fever cases.

If we want to forecast the next periods data using FIS, we need historical data for this periods. Because of the data is not available, we used the average of the same time data at previous periods [20]. The MAPE comparison between the difference of interval data which are included in the calculation of the average is shown in Table 6.

Table 6: The MAPE Results Of Difference Interval

Actual	Group	MAPE
Average of same month cases at fifth last year (2009-2014)	Lowlands	6%
	Mediumlands	12%
	Highlands	11%
Average of same month cases at second last year (2013-2014)	Lowlands	12%
	Mediumlands	17%
	Highlands	19%
Average of same month cases at last year (2014)	Lowlands	14%
	Mediumlands	21%
	Highlands	22%

Table 6 shows that the average calculation which involve the more data in a few years earlier could produce a smaller error. This is because of the data pattern can be found accurately with much more data especially if the data has a pattern that rises steadily every year in the same month.

Additionally, in this study, the number of fuzzy sets which used also affects the accuracy of

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forecasting results. Table 7 shows the MAPE comparison about the different of fuzzy set number.

While the MAPE of each membership functions representation are shown in Table 8.

Table 7: The MAPE of Fuzzy Set Number

Fuzzy Set Number	MAPE
Using 3 fuzzy set number, namely: L (*Low*), N (*Normal*), H(*High*)	53%
Using 5 fuzzy set number, namely: VL (*Very Low*), L (*Low*), N (*Normal*), H(*High*), VH(*Very High*)	50%
Using 7 fuzzy set number, namely: VVL (*Very Very Low*), VL (*Very Low*), L (*Low*), N (*Normal*), H(*High*), VH(*Very High*), VVH(*Very Very High*)	38%

Table 8: The MAPE of Membership Function Representation

Membership Function Representation	MAPE
Number of dengue fever case variable: simetris Population density variable: s-curves	38%
Number of dengue fever case variable: follow the data distribution Population density variable: s-curves	11%
Number of dengue fever case variable: flexible based on spread of data Population density variable: linear curves	14%

Based on Table 7 and Table 8 show that the forecasting results is very influenced by the number of fuzzy sets and fuzzy sets limitation. Optimal limits and match with the data pattern will produce good results.

4.3 Forecasting Results

The plot of comparison between actual data and dengue fever cases number forecasting results can be seen in Figure 9, Figure 10, and Figure 11. It shows an evidence that the number of dengue fever cases tends to increase significantly at the beginning of the year, and it tends to decrease significantly at the middle of the year. Another evidence is also shown on the last 5 years number of dengue fever cases.

Number of dengue fever cases for each district groups are different. The lowlands and mediumlands have higher number of dengue fever cases than the highlands. This evidence shows that geographical location affects the number of dengue fever cases. The geographical location is also related to weather, temperature and relative humidity of an area. Whereas each district group has its own unique characteristics. For example the highlands districts tends to be cloudy, with lower temperature and high humidity.

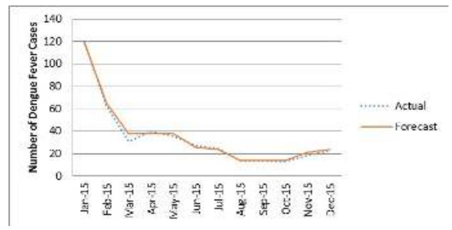

Figure 9 : Plot Of Comparison Between Actual Data And Forecasting Results In Lowlands

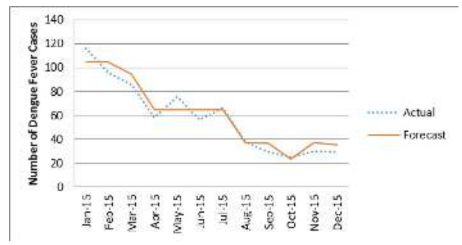

Figure 10 : Plot Of Comparison Between Actual Data And Forecasting Results In Mediumlands

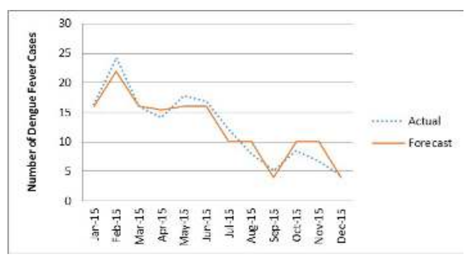

Figure 11 : Plot Of Comparison Between Actual Data And Forecasting Results In Highlands

5. CONLUSION

This paper presents a method to forecast the number of dengue fever cases in Malang Indonesia involving population density as independent variable. Based on the result, Forecasting number of dengue fever cases using Fuzzy Inference System in each sub-district groups produces the best forecasting accuracy by using model which the membership functions limitation as like the data distribution and the s-curve for population density variable.

The membership function representation of population density variables affect the accuracy of dengue fever cases number forecasting, where the population density variable is more suitable using the s-curve type than the linear curve. Besides that,

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The fuzzy sets number and fuzzy sets range are very influence to forecasting results. The optimal limitations and accordance with the data pattern will get a good forecasting. Suggestions for further research: grouping of the regions can made more detailed so it can describe the growth dengue fever cases number based on the characteristics of each area. We should use the membership functions are adjusted to the data distribution rather than using the membership function which generated automatically.

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