Rainfall Prediction Using Fuzzy Logic Method For Early Warning System In Flood Disaster Mitigation In Nganjuk

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Abstract. In general, flooding often causes problems in the form of flood disasters. This is because the flooding of shipments is unpredictable and causes a large area of impact. This problem will certainly have an impact on various life activities, such as threatened public safety, the emergence of congestion, and a decrease in agricultural, livestock, and fishery production. The cause of overland flow is the overflowing river in the upstream area due to high intesity of rainfall, therefore an early warning of flood predictions is needed to prepare to minimize the impact of flooding. One of the effective solutions is rainfall prediction for flood early detection systems. This study aims to predict the weather optimally and apply it to flood early warning system applications using fuzzy logic methods. The predicted rainfall intensity of the fuzzy logic model has an error rate of 4.58%.

Keywords: Flood, Fuzzy logic, Early warning system

1 Introduction

Climate change, which has occurred in recent decades, makes impacts upon many countries in the world, including Indonesia. One of the effects caused by this natural phenomenon is the shifting seasons which affect the rainfall patterns. Because it resulted in increased depth of rainfall in a short time. The accumulation of fixed annual rainfall within a short duration of rain will trigger an increase in flood intensity in Indonesia [1].

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According to the most recent data in 2021 taken from the National Agency for Disaster Management, the percentage of natural disasters often occuring in Indonesia which is flood disasters is approximately 37% [2]. An infographic of the percentage of national disaster events in 2021.

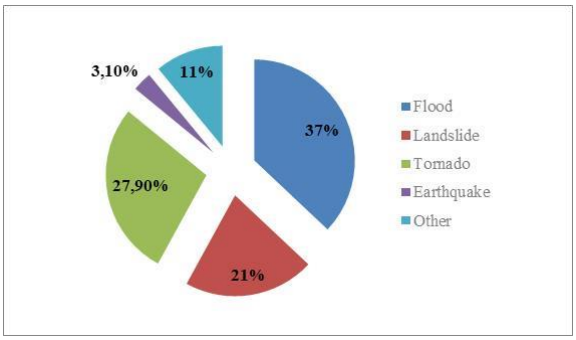

Fig. 1. Percentage of National Disaster Events in 2021

Forecasting data for the next few years or periods can be made by analyzing related data based on the order of retrieved data. Time-series analysis is one of the statistical procedures using in forecasting a probability of circumstances that may occur in the future to make a decision.

The analysis in this study using the fuzzy time series method with fuzzy sets was the basic concept of calculation with the determination of the length of an interval for the averages [3]. This method was applied to rainfall data in Nganjuk.

Based on the case, the authors want to predict rainfall using the fuzzy time series method of Chen's algorithm model. Fuzzy time series relies on time intervals which are very influential in the prediction results, as a result of which the formation of fuzzy relationships will be appropriate. The method for choosing an accurate interval length for prediction results is a homogeneous-based method or average-based fuzzy time series.

2 Literature Review

2.1. Fuzzy Time Series

Fuzzy time collection is a statistics prediction method that makes use of the concept of fuzzy set because of its calculation [4]. Prediction systems using data series can capture patterns from historical data and then use them to predict future data. The process does not require complicated learning on genetic alhoritma and neural networks making it easy to use and develop.
The difference between a fuzzy time series and a conventional series is in the value used for prediction, which is the fuzzy set of numbers that are real on the set of specified universes. Fuzzy sets can be a class of numbers with vague constraints.

2.2. Prediction Methods With Fuzzy Time Series

The Fuzzy Time Series method has an important initial stage that can be seen because it has an influence on the accuracy of the prediction day, namely by determining the length of the interval is very influential on the formation of fuzzy logic relationships on the results of prediction calculations [5].

2.3. Fuzzy Time Series Stages with Chen's Algorithm

In this study, the Fuzzy Time Series method with the Chen algorithm [6] [7] [8]:

1. Formation of the set of universes (U)

$$U = \{D_{min} - D_1, D_{max} + D_2\} \quad (1)$$

With D_1 dan D_2 is the value of a constant

2. Determining the Interval
Building the set of universes divided into several intervals with equal distances. To know many intervals can use average marching intervals. Thus forming a linguistic value in presenting fuzzy sets at intervals formed from the set of universes (U).

$$U = \{U_1 , U_2, ...,U_n\} \quad (2)$$

With U is the set of universes
u_i is the magnitude of the distance on U, to i = 1,2,.....,n.
A fuzzy set is a class or class of an object with a unitary set of degrees of membership.
For example U is the set of universes, U = {U_1 , U_2, ...,U_n} with which u_i towards U can be formulated as follows:

$$A_i = \frac{\mu_{Ai}(u1)}{u_1} + \frac{\mu_{Ai}(u2)}{u_2} + \frac{\mu_{Ai}(u3)}{u_3} + ...+ \frac{\mu_{Ai}(un)}{u_n} \quad (3)$$

μ_{A1} : U → (0,1). If μ_1 is a membership of A_i so μ_{A1} (u_i) is the degree of membership u_i towards A_i

3. Defining Fuzzy Logic Relations and Fuzzy Logic Relations Group
Define Fuzzy Logic Relations and create groups according to time. like the example if Fuzzy Logic Relations is in the form of $A_1 \rightarrow A_2$, $A_1 \rightarrow A_2$, $A_1 \rightarrow A_3$, $A_1 \rightarrow A_1$, then the Fuzzy Logic Relations formed is
$A_1 \rightarrow A_1, A_2 \rightarrow A_3$

4. Forecasting
If F(t-1) = A_i, then the forecast value must be according to each rule covering:
   a. If Fuzzy Logic Relations is from A_i none ($A_i \rightarrow$#), so F(t) = A_i
   b. If there is only one Fuzzy Logic Relations ($A_i \rightarrow A_j$), so F(t) = A_j

c. If ($A_i \rightarrow A_{j1}, A_{j2}, ..., A_{jk}$), so $F(t) = A_{j1}, A_{j2}, ..., A_{jk}$

5. Defuzzyfication

   For example $F(t) = A_{j1}, A_{j2}, ..., A_{jk}$ so $\hat{y}(t) = \frac{\sum_p^k m_{jp}}{k}$, with $\hat{y}(t)$ is defuzzyfication with m_{jp} is the middle value of A_{jp}

   Chen's algorithm has several shortcomings, namely that it does not take into account repetitions and there is no smaller weight on observations that are as old as.

2.4. Prediction Accuracy Rate

In this study to calculate the level of accuracy in a method is Mean Square Error (MSE) as follows[9]:

$$MSE = \frac{\sum_{t-1}^{n}(Y_t - \hat{Y}_{(t)})^2}{n} \quad (4)$$

With :

Y_t = Actual data of the period to-t

$\hat{Y}_{(t)}$ = Period prediction values to-t

n = The amount of data predicted

3 Research Method

The location of this study was in Nganjuk. Nganjuk is a district in East Java Province, Indonesia. it is bordered by means of Kediri Regency to the south, Jombang Regency to the east, Madiun Regency to the west, and Bojonegoro Regency to the north.

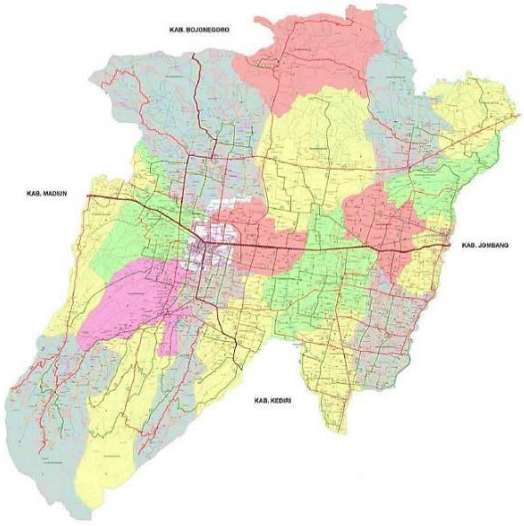

Fig. 2. Research Location Map

This research has the following stages of data analysis steps :

1. The process of determining average-based intervals
   analisis In the application of inverval determination there are 4 stages in the analysis process
   a. Calculates all absolute (lag) values
   b. Calculate all absolute lag values then divided by the amount of data
   c. Determination of the basis of the second process interval in divide by 2 (two)
   d. The result of the third process is adjusted to the interval table to get the average interval value

2. Fuzzy Time Series
   The stages in this study are the fuzzy time series process as follows :
   a. Formation of the set of universes (U).
   b. Determining the fuzzy set A_i as many intervals as have been divided in the previous stage.
   c. Perform the fuzzyfication process, converting non fuzzy variables into fuzzy variables.
   d. Define a fuzzy logical relationship $A_i \rightarrow A_j$ based on the A_i value that has been determined in the previous stage.
   e. From the results of the fuzzy logic relationship entered in the process of defuzzyfication or fuzzy logical relationship group using the Chen model.

Chen Model Rainfall Intensity Prediction Value

Model testing is based totally on the attention of the model accuracy gadget, conformity with the prediction price, specifically through evaluating the results of the prediction cost with the correctness fee of the prediction of the proper rainfall intensity [10].

Data Types and Sources

This study used secondary data from observations obtained from the Nganjuk Regency Public Works and Spatial Planning Office. Rainfall intensity data consists of 2016 to 2021[11]. The data taken annual data is presented in Table 1. Rainfall Intensity Data.

Table 1. Rainfall Intensity Data (mm)

Time	2016	2017	2018	2019	2020	2021
January	424	354	154	254	342	319
February	537	416	196	280	418	339
March	400	357	229	364	340	395
April	103	218	103	211	234	155
May	89	16	-	20	224	9
June	40	-	38	-	10	56
July	85	5	-	2	102	10
August	132	-	-	-	19	-
September	137	37	6	-	-	95
October	162	10	-	-	62	7
November	411	212	103	24	152	341
December	218	231	201	291	231	328
Amount	**2738**	**1856**	**1030**	**1446**	**2128**	**2114**
Average	**228**	**186**	**129**	**181**	**193**	**192**

Source : Central Agency on Statistics Nganjuk 2016 – 2021

4 Result and Discussion

This research uses the fuzzy Time collection approach which is used to predict rainfall intensity in Nganjuk Regency. The calculation results may be seen inside the following table:

Table 2. Result Prediction Rainfall Intensity

No	Time	Y (Output)	Y (Real)	% Error
1	2016	245	228	7.28
2	2017	172	186	7.33
3	2018	126	129	2.14
4	2019	189	181	4.56
5	2020	203	193	4.93
6	2021	190	192	1.14
Average				**4.58**

The results of the calculation of fuzzy time series analysis from the table above, in 2016 the error rate was 7.28%, in 2017 the error rate was 7.33%, in 2018 the error rate was 2.14%, in 2019 the error rate was 4.56%, in 2020 the error rate was 4.93%, in 2021 the error rate was 1.14% and from the results the average error rate was 4.58%.

5 Conclusion and Suggestion

This research is the Fuzzy Time Series method used to forecast rainfall in Nganjuk Regency. The data in this study is primary data obtained through the Nganjuk Regency Public Works and Spatial Planning Office. The test results showed that the Fuzzy Time Series method has an error rate of 4.58%.

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