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A solution to reduce the environmental impacts of earthquakes: Web GIS-based forecasting

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ABSTRACT

The impact of earthquakes in Aceh, Indonesia, goes beyond property damage and human casualties. The destruction caused by earthquakes has intensified environmental pollution, particularly with construction waste or debris. Construction waste and debris are a significant source of air, soil, and water pollution, releasing harmful chemicals and toxins that can cause respiratory problems, skin irritation, and other health issues. The earthquake that struck Aceh in 2004, for example, resulted in a massive amount of debris that had to be cleared. The debris disposal process not only caused environmental damage, but also resulted in significant health risks for workers involved in the cleanup. The 2018 earthquake in Lombok, Indonesia, resulted in over 50,000 buildings being damaged or destroyed, generating an estimated 1.5 million tons of debris. The web GIS-based earthquake forecasting tool developed in this study has the potential to help preventing some of these environmental issues. By providing more accurate and timely earthquake predictions, this tool can help authorities better plan for post-disaster recovery efforts, including the proper management and disposal of construction waste and debris. Additionally, this tool can assist in identifying areas where construction activity should be avoided or minimized, reducing the amount of waste generated during the construction process. The application of the fuzzy time series method in the forecasting tool can improve the accuracy of earthquake predictions, making it easier to prepare for and mitigate the environmental impact of earthquakes. Overall, the web GIS-based earthquake forecasting tool developed in this study can help reducing the negative impact of earthquakes on the environment and public health. By improving our ability to predict earthquakes, we can better prepare for their aftermath, reduce the amount of waste generated during recovery efforts, and minimize the long-term environmental impact of earthquakes in Aceh, Indonesia.

Keywords: Environmental impacts, Earthquake, GIS, Aceh.
Article type: Research Article.

INTRODUCTION

Indonesia is the world's largest archipelago, consisting of over 17,000 islands with a total land area of 1.9 million square kilometers. The country is located in a region that is prone to earthquakes and volcanic activity, with the infamous Ring of Fire passing through the country. As such, earthquakes are a common occurrence in Indonesia, and the country has experienced some of the most devastating earthquakes in recent history (Ghifari *et al.* 2018). According to data from the United States Geological Survey (USGS), Indonesia has had over 11,000 earthquakes with a magnitude of 4.0 or greater in the past 10 years. In 2018 alone, the country had 1,923 earthquakes with a magnitude of 4.0 or greater (Muyasaroh & Sudarmilah 2019). This high frequency of earthquakes poses a significant threat to the safety and security of the Indonesian people, as well as to the infrastructure and buildings in the country. Another significant environmental issue in Indonesia is pollution, particularly with construction waste or debris. The construction industry in Indonesia is one of the largest contributors to waste generation, with over 12 million tons of waste produced in 2018 alone (Kamaruddin *et al.* 2022). This waste often ends up in

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landfills, which can lead to environmental degradation and health hazards. According to the Ministry of Environment and Forestry, the amount of waste generated by the construction industry in Indonesia is expected to increase by 5% annually (Fitriani *et al.* 2022). This increase is due to the country's rapid urbanization and infrastructure development, which requires a significant amount of construction. The Indonesian government has recognized the importance of addressing these environmental issues and has taken steps to mitigate their impacts. For example, in 2018, the government passed a regulation that requires construction companies to recycle at least 25% of their waste. Additionally, the government has implemented various programs to encourage the use of environmentally friendly building materials and construction techniques (Kubota *et al.* 2020). Geographically, the territory of Indonesia has unique characteristics. Namely, Indonesia is located at the meeting area of three tectonic plates (triple junction plate converge; Suda 2016). The three plates are the Eurasian Plate, the Pacific Ocean Plate, and the Indo-Australian Plate, where the Indo-Australian Plate is actively moving to the north with a relative speed of V= 5-7 cm/year, as well as the Pacific Ocean Plate, which is actively moving westward with an almost the same rate (Mustafa 2010), while the Eurasian Plate is relatively passive. The consequences of Indonesia's geography in the Triple Junction area make Indonesia an area prone to earthquakes (high seismicity) and tectonically unstable (Ghifari *et al.* 2018). One area in Indonesia with high seismicity is the Aceh Province. The frequent occurrence of earthquakes proves it with intervals between earthquakes that are not long enough with a range of medium to increased magnitudes (Muyasaroh & Sudarmilah 2019). This can happen, considering that the Aceh region is located at the confluence of two plates of the earth's crust, namely the Eurasian plate, which is relatively stationary, and the Indo-Australian plate, which moves northward and Aceh can be categorized as an earthquake-prone area (Hidayati *et al.* 2014). At the confluence of the Eurasian and Indo-Australian plates, there is subduction or infiltration of each other. Namely, the Eurasian plate infiltrates under the Indo-Australian plate. As a result of the interaction of the two crustal plates, there are many folds (mountains) and faults in the Aceh area, including the Tripa segment, the Aceh segment, and the Seulimeum segment. Two major earthquakes in the last ± 8 years that rocked Aceh and captured public attention were the Aceh Earthquake on December 26, 2004 and the Aceh Earthquake, which recently occurred on 11 April 2012 (Putri *et al.* 2016). Computer-based technology has become ubiquitous in human life, with many different fields utilizing it to develop theories and applications through a variety of information systems. Among these systems, Geographic Information System (GIS; "Sistem Informasi Geografis Pemetaan Potensi Sma/Smk Berbasis Web; Studi Kasus : Kabupaten Kebumen") 2014) is particularly popular, especially for mapping surveys. GIS has been utilized by both government and private agencies for planning, monitoring, and evaluating development outcomes. GIS is a valuable tool for researchers, managers, and decision-makers to analyze map data using computer technology to solve problems, make decisions, or formulate spatial policies (Ramadhani *et al.* 2013). The method that is suitable for this problem is Fuzzy Time Series, which is a new concept proposed by Song & Chissom based on fuzzy set theory and the idea of linguistic variables and their application by Zadeh. Fuzzy time series is used to solve forecasting problems where historical data are linguistic values (Mirzaei Talarposhti *et al.* 2016). In forecasting problems, for example, historical data are not in the form of real numbers but linguistic data. In this case, no conventional time series model can be applied, while the fuzzy time series model can be used more precisely. Previous research is based on fuzzy set theory, fuzzy logic, and approximate reasoning. Another strong reason this method has a smaller error value than other forecasting methods (Dewi *et al.* 2014).

Literature Review

In simple terms, the system can be interpreted as a collection or set of elements, components, or variables that are organized, interact with each other, depend on each other, and are integrated. The system's structure is the elements that make up the system. In contrast, the system process explains how each aspect forms the system. A system can be formulated as any collection of components or subsystems designed to achieve a goal. The general model of a system consists of inputs, processes, and outputs. This is a straightforward system concept, considering a system can have several inputs and outputs simultaneously. In addition, an approach also has specific characteristics or properties that characterize it, can be said to be a system. A system is a form of integration between one component and another because the system has different goals for each case that occurs in the system. Designs can be classified from several points of view, such as abstract systems, natural systems, deterministic systems, and open and closed systems. The source of information is data. Data is a fact that describes an event and is an actual entity, and is a form that is still raw, so that it needs to be further processed through a model to produce information. Data is a source of information material. Information processors carry out the change of data into information. Information processing is one of the key elements in the conceptual system. Information processing can include computer elements, non-computer elements, or a combination thereof. In digital form, GIS data represents real objects (buildings, islands, land elevations, etc.). Types of data are grouped into two, namely vector data and raster data. Vector-type maps store spatial data from points, lines, and polygons. The most common vector map format is a shapefile. Vector types store discrete data, such as buildings, rivers, islands, etc. Raster maps are stored in a matrix/grid consisting of many cells. The raster type stores continuous data (such as ground elevation, rainfall, etc.). An earthquake occurs when the earth experiences vibrations caused by a sudden release of energy. This energy is typically generated by the movement of tectonic plates, resulting in the breaking of rock layers in the Earth's crust. As the energy is released, it travels in all directions as earthquake waves, which can be felt on the Earth's surface. The accumulation of energy from tectonic plate movement is what leads to the occurrence of earthquakes.

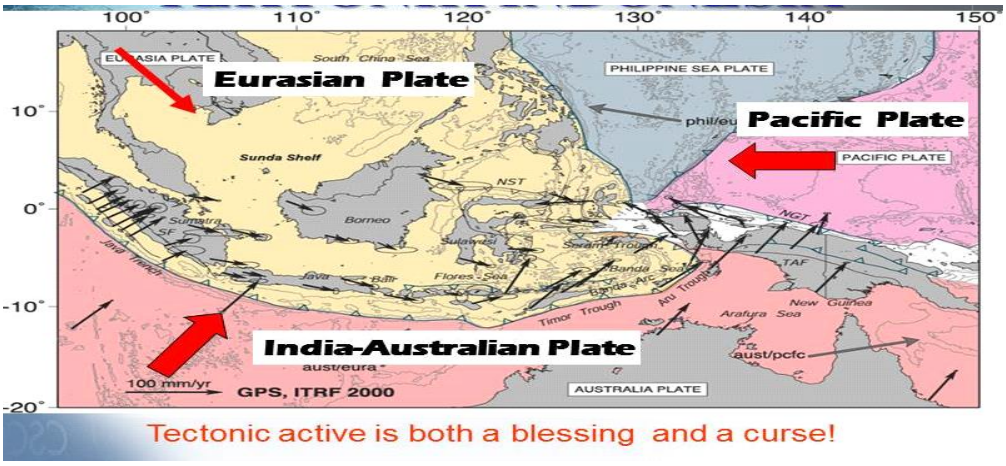

Fig. 1. Indonesian tectonics.

Plate tectonics is a complex scientific theory that explains the cause of earthquakes. This theory suggests that the earth's surface is divided into several large tectonic plates that float above the hot and liquid asthenosphere. As these plates are free to move, they interact with each other, particularly at their borders, creating active tectonic conditions that result in earthquakes, volcanoes, and highland formation. This theory combines earlier ideas such as Continental Drift and Sea Floor Spreading, providing a more comprehensive explanation of the movements and interactions of these tectonic plates. One area in Indonesia with high seismicity is the Aceh Province. It is proven by the frequent occurrence of earthquakes with not long time intervals between earthquakes with a medium to high magnitude range. This can happen, considering that the Aceh region is located at the confluence of two plates of the earth's crust, namely the Eurasian plate, which is relatively stationary, and the Indo-Australian plate, which moves northward. Forecasting is a process of predicting what will happen in the future. The forecasting process is carried out by the scientific method and systematically. Qualitative properties such as feelings, experiences, and others are essential in forecasting and using scientific or organized procedures. To estimate a variable, it should be considered and studied in advance. To examine how the history of the development of a variable, we will observe a series of variable values according to time. Time series is data collected from time to time to describe the development of the mass activity, the product of a production, population, sales results, and so on. Periodic data analysis makes it possible to know the outcome of one or several events and their relationship or influence on other occasions. For example, whether an increase follows the upraise in fertilizer use in rice production; or whether an increase follows the number of salary increases in work performance. The time series forecasting process does not involve independent variables other than the time index (t) itself, thus ignoring other independent factors. Therefore, a model of data behavior is sought, not what factors cause data fluctuations. A time series refers to a collection of data points in which the variables are recorded in chronological order, usually at regular intervals such as yearly, monthly, or quarterly. Time series data enables the observation and analysis of patterns and changes in variable values over time. Time Series Data Forecasting predicts what will happen based on past historical data. A time series is a collection of regular observations on a variable over the same and successive periods. A relationship between demand and time can be formulated and used to predict future demand levels by studying how a variable changes over time.

MATERIALS AND METHODS

The research was conducted at several BMKG offices in several points or areas prone to earthquakes, namely BMKG Sabang, BMKG Banda Aceh, BMKG Meulaboh, BMKG Sigli, BMKG Tamiang and BMKG Tapaktuan in Aceh Province.

1. The first step: Inputting data that will be used as forecasting data in this experiment, is carried out on earthquake data from the 2012,2013,2014,2015,2016
2. The second step: establishing the universal set of discourse U for which the fuzzy set is being defined. Once the relevant data has been computed, the minimum and maximum values can be determined. The universal set of speech U can be set as U = [A, B] depending on the obtained value.
3. The third step: determining the quantity of intervals and their respective lengths within the universal set (U). This is accomplished in order to identify the number of separations that partition the versatile set (U) into multiple segments. The formula used to determine the quantity of breaks is as follows:

$$BK = 1+3.3 \log n \quad \textbf{(1)}$$

   where n is the number of data. To determine the interval length, divide the range of data (the difference between the maximum and minimum values) by the number of classes. It is important to note that the number of classes must be an odd number.
4. Fourth step: Determining the linguistic set based on the predetermined interval length.
5. Fifth step: Fuzzification of historical data values, where fuzzy logical relationship Aj => Ak means that if the enrollment value in the year i is Aj, then year i+1 is Ak. Aj, as the left side of the relationship, is referred to as the current state, and Ak, as the right side of the relationship, is referred to as the next state. In addition, if there is a repetition of the relationship, then it is still counted once.
6. Sixth Step: Dividing the fuzzy logical relationship obtained into several parts based on the left side (current state).
7. Step 7: Determining the Fuzzy Logic Relationship Group (FLRG)
8. Step 8: Carrying out the forecasting and defuzzification process based on the established FLRG.
9. Step 9: Finding the error value with the Average Forecasting Error Rate (AFER) Obtained from the sum of all error values for each period squared and then divide by the number of periods. In general, the smaller the percentage of the AFER value, the more accurate the forecasting method, with the following calculation formula:

$$\text{AFER} = \frac{|A_i - F_i|/A_i}{n} * 100\ \% \qquad \textbf{(2)}$$

where:
Ai = Actual value on the data to - i
Fi = Forecasting result value for data to - i
n = total number of data

RESULT AND DISCUSSION

In designing this earthquake-level forecasting application system, problem analysis plays an important role in making details of the application to be built. Problem analysis is a step in understanding the problem before taking action or final resolution decisions. System analysis aims to identify a number of problems that cover all aspects of the designed system including the operating environment from inputting earthquake data to forecasting results from each point sought. The use of this forecasting system is expected to have a good impact on the BMKG Aceh, since to date there has been no forecasting application for earthquakes used by the BMKG Aceh, so that it cannot predict earthquakes for the coming year and cannot know areas that are prone to earthquakes on earth. In terms of forecasting, the fuzzy time series method can be used to predict/predict earthquake-prone areas with greater strength than before. By this application, it is hoped that this application can help in the earthquake forecasting process, so that people in general can find out more quickly about earthquakes in the future and more quickly watch out. The problem is in taking data on current earthquake conditions and earthquake data from the past and then predicting these conditions in the future with the assumption that the past will happen again in the future. To

build an earthquake level forecasting application, it is designed according to the concept rules that exist in the Fuzzy Time Series method. The application to be built is arranged into 2 parts, namely the admin section and the user section. The admin section is the section that will fully control the application. All activities using earthquake forecasting applications will be carried out in this section. Therefore this section cannot be accessed by users other than admin, while the user section can be used by anyone. At this stage of system design, it aims to determine the steps for the operation of the overall system application starting from the context diagram design, DFD (Data Flow Diagram) design, ERD (Entity Relationship Diagram), table structure and interface design.
In the manual calculation of the Fuzzy Time Series method, there are several steps to be taken, the following is an explanation.

1. Step 1: input actual data
   This expriment analyzed earthquake data from the years 2012 to 2016. In Table 1 the following is the actual earthquake data taken as a forecast.

Table 1. Aceh Earthquake Actual Data Table.

Date	Time	Latitude	Longitude	Mag(strength)
06/01/2012	13.58.33	2.16	96.25	3
14/02/2012	02.20.38	3.14	96.66	7
29/03/2012	09.27.11	1.32	95.61	4.9
14/04/2012	08.23.51	2.13	96.74	5
14/06/2012	22.59.26	2.23	95.97	4.2
17/08/2012	06.06.32	3.25	96.79	4.4
19/08/2012	01:57:02	1.18	96.32	4
09/09/2012	09:13:06	2.94	96.01	4.6
24/11/2012	14:04:56	2.53	97.68	4.3
27/11/2012	12:00:27	2.11	96.5	4.4
28/11/2012	23:03:22	4.77	96.65	3.5
06/12/2012	18:22:33	2.25	95.6	2.7
05/01/2013	03:24:32	2.47	96.5	3.2
06/02/2013	00:43:52	1.09	97.32	3.3
16/03/2013	11:55:05	4.76	96.2	2.8
29/04/2013	13:43:00	3.89	97.32	4.3
31/05/2013	19:52:42	2.41	97.83	2.9
07/06/2013	14:12:21	2.61	97.91	4.1
06/07/2013	10:06:54	2.46	95.94	3.8
30/08/2013	09:01:44	1.65	96.81	4.2
24/09/2013	07:03:04	2.1	95.45	5
04/10/2013	10:10:09	2.33	96.66	3.4
22/11/2013	10:43:42	4.76	95.84	5.1
10/12/2013	07:37:26	5.94	95.9	1
18/02/2014	10:15:54	1.07	96.95	3.4
19/02/2014	07:36:04	4.74	96.12	3

05/05/2014	15:06:26	2.47	96.13	4
09/05/2014	16:40:55	4.42	97.01	3
09/05/2014	20:00:47	2.57	95.95	4.4
29/06/2014	08:11:54	4.42	95.93	4
05/07/2014	14:50:31	4.87	96.91	4.9
07/09/2014	13:31:37	4.95	97.25	2
14/09/2014	10:28:19	5.3	97.16	2.6
08/10/2014	11:15:39	5.23	94.73	4.5
03/11/2014	05:05:53	5.02	84.78	3.6
17/12/2014	16:28:37	2.7	95.7	3.6
27/01/2015	10:59:58	2.32	94.42	4.8
02/02/2015	20:13:59	1.4	95.72	4.5
06/03/2015	14:03:54	1.62	97.15	4.8
09/03/2015	11:47:42	1.05	97.27	3.6
21/05/2014	02:42:07	2.65	97.13	6
01/06/2015	14:07:50	4.54	96.29	3.8
11/06/2015	01:18:19	4.15	94.95	4
19/08/2015	00:46:40	2.65	95.93	5
04/09/2015	08:02:12	4.81	97.64	3.3
28/10/2015	04:57:12	4.62	96.07	3.4
02/11/2015	11:10:24	2.02	95.7	3.4
07/12/2015	16:35:15	3.22	96.39	4.5
30/01/2016	23:25:13	3.19	95.64	3.9
12/02/2016	15:33:45	2.02	97.07	4.1
31/03/2016	19:38:45	3.03	96.11	3.1
01/05/2016	07:08:22	4.57	95.84	3.6
06/05/2016	04:54:04	4.52	96.42	3.5
27/06/2016	03:50:51	3.48	95.84	4.9
03/07/2016	23:10:59	3.98	95.45	4.8
31/08/2016	13:13:35	1.23	96.17	4.7
21/09/2016	21:13:01	2.09	95.08	3.8
28/10/2016	01:47:54	1.23	96.83	3.5
04/11/2016	09:22:52	3.82	97.23	4.4
18/12/2016	19:24:45	5.36	94.54	5.1

2. Step 2: In order to define the fuzzy set, it is necessary to establish the universal set of discourse U that it pertains to. The calculation of the actual data yields a minimum value of 1 and a maximum of 7. Utilizing these values, we can define the universal set of speech U [1,7].

3. Step 3: To determine the number of intervals that divide the universal set (U) into multiple parts, it is necessary to calculate the length and quantity of these intervals. The formula below can be used to calculate the number of intervals:

   BK = 1+3.3 log n

   where n is the number of data. The study utilized a dataset comprising 60 data points, yielding a result of 6.54. To ensure an odd number of intervals, the value was rounded up to the nearest odd integer, resulting in 7 intervals. The length of each interval class was determined to be 0.87.
4. Step 4: Determining the linguistic set based on the specified interval length.
   Based on the length of the interval obtained, the class that will be divided into 9 intervals is obtained after the data has been sorted previously, namely U1 = [1,3], U2 = [3,3.4], U3 = [3.4,3.6], U4 = [3.6,3.9], U5 = [4,4.2], U6 = [4.2,4.4], U7 = [4.5,4.8], U8 = [4.8,5], U9 = [5.1,7]. Then 9 linguistic values are determined that make up 9 fuzzy sets A1, A2, A3, A4, A5, A6, A7, A8, A9 which in the universe of U talk are A1 = 1, A2 = 3, A3 = 3.4, A4 = 3.6, A5 = 4, A6 = 4.2, A7 = 4.5, A8 = 4.8, A9 = 5.1.
5. Step 5: Fuzzification of values from historical data.
   The linguistic values presented in the following table were derived from historical data that was fuzzified:

Table 2. Historical Data Fuzzification.

Date	Time	Latitude	Longitude	Mag	Fuzzified
06/01/2012	13:58:33	2.16	96.25	3	A2
14/02/2012	02:20:38	3.14	96.66	7	A9
29/03/2012	09:27:11	1.32	95.61	4.9	A8
14/04/2012	08:23:51	2.13	96.74	5	A8
14/06/2012	22:59:26	2.23	95.97	4.2	A6
17/08/2012	06:06:32	3.25	96.79	4.4	A6
19/08/2012	01:57:02	1.18	96.32	4	A5
09/09/2012	09:13:06	2.94	96.01	4.6	A7
24/11/2012	14:04:56	2.53	97.68	4.3	A6
27/11/2012	12:00:27	2.11	96.5	4.4	A6
28/11/2012	23:03:22	4.77	96.65	3.5	A3
06/12/2012	18:22:33	2.25	95.6	2.7	A1
05/01/2013	03:24:32	2.47	96.5	3.2	A2
06/02/2013	00:43:52	1.09	97.32	3.3	A2
16/03/2013	11:55:05	4.76	96.2	2.8	A1
29/04/2013	13:43:00	3.89	97.32	4.3	A6
31/05/2013	19:52:42	2.41	97.83	2.9	A1
07/06/2013	14:12:21	2.61	97.91	4.1	A5
06/07/2013	10:06:54	2.46	95.94	3.8	A4
30/08/2013	09:01:44	1.65	96.81	4.2	A6
24/09/2013	07:03:04	2.1	95.45	5	A8
04/10/2013	10:10:09	2.33	96.66	3.4	A3
22/11/2013	10:43:42	4.76	95.84	5.1	A9

10/12/2013	07:37:26	5.94	95.9	1	A1
18/02/2014	10:15:54	1.07	96.95	3.4	A3
19/02/2014	07:36:04	4.74	96.12	3	A2
05/05/2014	15:06:26	2.47	96.13	4	A5
09/05/2014	16:40:55	4.42	97.01	3	A2
09/05/2014	20:00:47	2.57	95.95	4.4	A6
29/06/2014	08:11:54	4.42	95.93	4	A4
05/07/2014	14:50:31	4.87	96.91	4.9	A8
07/09/2014	13:31:37	4.95	97.25	2	A1
14/09/2014	10:28:19	5.3	97.16	2.6	A1
08/10/2014	11:15:39	5.23	94.73	4.5	A7
03/11/2014	05:05:53	5.02	84.78	3.6	A4
17/12/2014	16:28:37	2.7	95.7	3.6	A4
27/01/2015	10:59:58	2.32	94.42	4.8	A8
02/02/2015	20:13:59	1.4	95.72	4.5	A7
06/03/2015	14:03:54	1.62	97.15	4.8	A8
09/03/2015	11:47:42	1.05	97.27	3.6	A4
21/05/2014	02:42:07	2.65	97.13	6	A9
01/06/2015	14:07:50	4.54	96.29	3.8	A4
11/06/2015	01:18:19	4.15	94.95	4	A5
19/08/2015	00:46:40	2.65	95.93	5	A8
04/09/2015	08:02:12	4.81	97.64	3.3	A2
28/10/2015	04:57:12	4.62	96.07	3.4	A3
02/11/2015	11:10:24	2.02	95.7	3.4	A3
07/12/2015	16:35:15	3.22	96.39	4.5	A7
30/01/2016	23:25:13	3.19	95.64	3.9	A4
12/02/2016	15:33:45	2.02	97.07	4.1	A5
31/03/2016	19:38:45	3.03	96.11	3.1	A2
01/05/2016	07:08:22	4.57	95.84	3.6	A4
06/05/2016	04:54:04	4.52	96.42	3.5	A4
27/06/2016	03:50:51	3.48	95.84	4.9	A8
03/07/2016	23:10:59	3.98	95.45	4.8	A8
31/08/2016	13:13:35	1.23	96.17	4.7	A7
21/09/2016	21:13:01	2.09	95.08	3.8	A4
28/10/2016	01:47:54	1.23	96.83	3.5	A3
04/11/2016	09:22:52	3.82	97.23	4.4	A6
18/12/2016	19:24:45	5.36	94.54	5.1	A9

Table Description 2:

a. On 6 December, 2012 data 2.7 is included in group A1 in the range of values (1, 2.9)
b. 9 May 2014 data 4.4 is included in group A6 in the range of values (4.2, 4.4)
c. 27 June 2016 data 4.9 is included in the A8 group in the range (4.8.5)

6. Step 6: Establishing a Fuzzy Logic Relationship (FLR)

Table 3. FLR (Fuzzy Logic Relationship).

Date	Time	Lat	Long	Mag	Fuzzified	FLR
06/01/2012	13.58.33	2.16	96.25	3	A2	A2 -> A9
14/02/2012	02.20.38	3.14	96.66	7	A9	A9 -> A8
29/03/2012	09.27.11	1.32	95.61	4.9	A8	A8 -> A8
14/04/2012	08.23.51	2.13	96.74	5	A8	A8 -> A6
14/06/2012	22.59.26	2.23	95.97	4.2	A6	A6 -> A6
17/08/2012	06.06.32	3.25	96.79	4.4	A6	A6 -> A5
19/08/2012	01.57.02	1.18	96.32	4	A5	A5 -> A7
09/09/2012	09.13.06	2.94	96.01	4.6	A7	A7 -> A6
24/11/2012	14.04.56	2.53	97.68	4.3	A6	A6 -> A6
27/11/2012	12.00.27	2.11	96.5	4.4	A6	A6 -> A3
28/11/2012	23.03.22	4.77	96.65	3.5	A3	A3 -> A1
06/12/2012	18.22.33	2.25	95.6	2.7	A1	A1 -> A2
05/01/2013	03.24.32	2.47	96.5	3.2	A2	A2 -> A2
06/02/2013	00.43.52	1.09	97.32	3.3	A2	A2 -> A1
16/03/2013	11.55.05	4.76	96.2	2.8	A1	A1 -> A6
29/04/2013	13.43.00	3.89	97.32	4.3	A6	A6 -> A1
31/05/2013	19.52.42	2.41	97.83	2.9	A1	A1 -> A5
07/06/2013	14.12.21	2.61	97.91	4.1	A5	A5 -> A4
06/07/2013	10.06.54	2.46	95.94	3.8	A4	A4 -> A6
30/08/2013	09.01.44	1.65	96.81	4.2	A6	A6 -> A8
24/09/2013	07.03.04	2.1	95.45	5	A8	A8 -> A3
04/10/2013	10.10.09	2.33	96.66	3.4	A3	A3 -> A9
22/11/2013	10.43.42	4.76	95.84	5.1	A9	A9 -> A1
10/12/2013	07.37.26	5.94	95.9	1	A1	A1 -> A3
18/02/2014	10.15.54	1.07	96.95	3.4	A3	A3 -> A2
19/02/2014	07.36.04	4.74	96.12	3	A2	A2 -> A5
05/05/2014	15.06.26	2.47	96.13	4	A5	A5 -> A2
09/05/2014	16.40.55	4.42	97.01	3	A2	A2 -> A6
09/05/2014	20.00.47	2.57	95.95	4.4	A6	A6 -> A4
29/06/2014	08.11.54	4.42	95.93	4	A4	A4 -> A8
05/07/2014	14.50.31	4.87	96.91	4.9	A8	A8 -> A1

07/09/2014	13.31.37	4.95	97.25	2	A1	A1 -> A1
14/09/2014	10.28.19	5.3	97.16	2.6	A1	A1 -> A7
08/10/2014	11.15.39	5.23	94.73	4.5	A7	A7 -> A4

Table Description 3:

a. 6 January 2012 and 14 February 2012 obtained from the number of range A2 3 and range A9 7 which will form a fuzzy logic relationship as in the FLR table is A2 => A9 to unite each period to be related.
b. 14 June 2012 and 17 August 2012 obtained from the number of range A6 4.2 and range A6 4.4 which will form a fuzzy logic relationship as in the FLR table is A6 => A6 to unite each period to be related.
c. 21 May 2014 and 01 June 2015 obtained from the number of range A9 6 and range A4 3.8 which will form a fuzzy logic relationship as in the FLR table is A9 => A4 to unite each period to be related.
d. 28 October 2016 and 06 December 2016 obtained from the number of range A3 3.5 and range A6 4.4 which will form a fuzzy logic relationship as in the FLR table is A3 => A6 to unite each period to be related.

7. Step 7 : Determining the Fuzzy Logic Relationship Group (FLRG)
Table 4 presents the Fuzzy Logic Relationship (FLR). Using this table, we can form a Fuzzy Logic Relationship Group (FLRG) by removing duplicate FLRs that have the same left-hand side (LHS) or current state can be grouped together. This process results in the formation of the FLRG table presented in the following Table 4.

Table 4. FLR (Fuzzy Logic Relationship).

Current state	**Next state**
A1	A1, A2, A3, A5, A6, A7
A2	A1, A2, A3, A4, A5, A6, A9
A3	A1, A2, A3, A6, A7, A9
A4	A3, A4, A5, A6, A8, A9
A5	A2, A4, A7, A8
A6	A1, A3, A4, A5, A6, A8, A9
A7	A4, A6, A8
A8	A1, A2, A3, A4, A6, A7, A8
A9	A1, A4, A8

Table Description:

a. The process of creating a Fuzzy Logic Relationship Group (FLRG) involves eliminating any duplicate or identical FLRs. Next, any FLRs that share the same left-hand side (LHS) or current state are consolidated into a single group such as: A1 => A1, A2, A3 , A5, A6, A7
b. The creation of Fuzzy Logic Relationships (FLRs) involves the elimination of identical or duplicate FLRs. Next, FLRs that possess the same left-hand side (LHS) or current state are consolidated into a singular group such as: A2 => A1, A2, A3 , A4, A5, A6, A9
c. The creation of a Fuzzy Logic Relationship Group (FLRG) involves the elimination of any identical or duplicated FLRs. Next, FLRs with identical left-hand sides or current states are consolidated into a singular group. This process yields a more organized and simplified FLRG such as: A3 => A1, A2, A3 , A6, A7, A9 and so on.
b. To make the forecasting process easier, it is possible to first calculate all possible values from the fuzzification results for each group. For groups with current state A1 => 3.35, A2 => 3.47, A3 => 3.53 and so on for other groups as can be seen in table 5 below:

Table 5. FLRG (Fuzzy Logic Relationship Group).

Current State	Forecasted
A1	3.35
A2	3.471428571
A3	3.533333333
A4	4.183333333
A5	3.975
A6	3.728571429
A7	4.2
A8	3.5
A9	3.133333333

Table Description:

a. The value of A1 => 3.35 is obtained from (A1,A2,A3,A5,A6,A7)/6 = 3.35
b. The value of A2 => 3.47 is obtained from (A1,A2,A3,A4,A5,A6,A9)/7 = 3.47
c. The value of A3 => 3.53 is obtained from (A1,A2,A3,A6,A7,A9)/6 = 3.53
d. The value of A4 => 4.18 is obtained from (A3,A4,A5,A6,A8,A9)/6 = 4.18

The calculation steps in determining the fuzzification results for each group to determine the fuzzy logic relationship group (FLRG) are the same.

8. Step 8 : Carrying out the forecasting and defuzzification process based on the established FLRG.
9. Step 9 : calculating the error value with AFER
   In this step, the calculated error value is the average error value with the AFER of each data that you want to predict. An example for calculating the error value from forecasting results on January 6, 2012 is:

$$\begin{aligned} \text{AFER} &= \frac{|A_i - F_i|}{n} * 100\% \\ &= \frac{|3-3,47|/3}{60} * 100\% \\ &= \frac{0,1566}{60} * 100\% \\ &= 0,0026\ \% \end{aligned}$$

   Then the AFER value obtained is 0.0026% for forecast data on 6 January, 2012. After calculating for monthly forecasts, the average obtained for AFER is 0.0034%.

CONCLUSION

Based on the description that has been discussed in this study, it can be concluded:

1. Applications for forecasting the level of earthquakes in Aceh based on WebGIS using the Fuzzy Time Series method built with DFD (Data Flow Diagrams), using the PHP programming language and MYSQL database, mapping using the Google Map API to display peda to webgis.
2. The Fuzzy Time Series forecasting method used in earthquake forecasting applications is a good method because the search has an error value with Afer, where the smaller the error value, the more accurate it is.
3. Forecasting results show that in some areas in Aceh, the value of forecasting results is greater than the magnitude value of previous years

In summary, the conclusion drawn from the study suggests that the use of the Fuzzy Time Series method in earthquake prediction applications can help to prepare for potential earthquakes, which can in turn help to prevent or minimize environmental pollution.

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