Time Series Visualization (TSV) of Earthquakes in The Cilacap and Surrounding Earthquake Active Zone using QGIS And USGS Data Set

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Article Info :	ABSTRACT
Article History : Received : 12 Dec 2022 Revised : 16 July 2023 Accepted : 21 July 2023 Available Online : 13 August 2023 **Keyword :** **Earthquake, QGIS, Time Series Visualization**	*Earthquakes in Cilacap often occur with a strength above 5 SR or with a smaller strength. This condition means that earthquake research in the Cilacap area will always be needed. This study aims to display a visualization of the time series of earthquakes in the Cilacap area using QGIS and the USGS dataset. The data set used is the earthquake data set around the Cilacap area from USGS with a time span from 1918 to 2021. The data boundaries of this study are Latitude 7.324˚, Longitude 107.941˚, and Latitude -10.407˚, Longitude 111.116˚. The results of spatial data visualization using the heatmap technique are then analyzed temporally using the Temporal function in the QGIS software. The results of the temporal analysis with frames per year produce 104 frames. Visualization of earthquake data in a time series can show changes in the pattern of earthquake magnitude density and show changes in the geographical location of earthquake points from year to year.*

1. INTRODUCTION

Earthquakes in Cilacap often occur, both with a magnitude of more than 5 on the Richter Scale (SR) which is felt by residents, and with a smaller magnitude. BMKG states that the southern part of Java, especially Cilacap, is an area that needs to always be aware of the dangers of earthquakes and tsunamis because it has a dense population and is located on the South Coast of Java, which faces directly the collision zone of the Indian Ocean plate and the Eurasian plate (Pranita, 2022). The geographical location of Cilacap Regency is shown in Figure 1 below. With the seismic conditions that have been mentioned, studies on earthquakes in the Cilacap area will always be needed to determine the current seismic conditions.

Research on the earthquake in Cilacap includes risk analysis and soil vulnerability in 2016 and 2021. The results of the 2016 Risk Analysis study state that the entire city of Cilacap is classified in the medium hazard level category, with soil vulnerability levels ranging from high to low (Muhaimin, Tjahjono and Darmawan, 2016). Five years later, the vulnerability of the land in the city of Cilacap was again analyzed by the BMKG Research Team, resulting in the conclusion that the vulnerability of the land in areas with a dense distribution of buildings and harder soil structures had a higher vulnerability (Edison et al., 2021). Meanwhile, research on land vulnerability in one of the sub-districts in the southern region of Cilacap Regency, namely Adipala District, stated that this area has high land vulnerability (Wachidah and Agustin, 2021). These three studies have spatial visualization map output but have not compiled it in a time-series manner. So it cannot explain descriptively the fluctuations in seismic conditions over time.

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Figure 1. Map of Cilacap Regency Administrative Boundaries

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Time-series visualization of spatial data can be done using the Temporal Controller function in Quantum GIS (QGIS) software and presented in Heatmap form. The aim of using a heatmap is so that data with maximum values or data density can be easily displayed (Liu et al., 2019; Flenniken, Stuglik and Iannone, 2020). It is hoped that by utilizing the Temporal Controller function and Heatmap visualization, fluctuations in the magnitude and distribution of earthquake data sets in the Cilacap area can be seen from time to time.

2. RESEARCH METHODS

2.1. Time and Place of Research

This research was carried out in the Software and Applied Computing Laboratory of the Informatics Engineering Study Program for 18 weeks. The data set used is the Cilacap region Earthquake data set from the USGS with a time span of 1918 to 2021. The spatial boundaries of the data set stretch from -7,324 ˚LS, 107,941˚E to -10,407˚LS, 111,116˚E.

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2.2. Tools and Materials

The tools and materials used in the research are presented in Table 1 below.

Table 1. List of Research Tools and Materials

No.	Names of Tools and Materials	Information
(1)	(2)	(3)
a.	Computer/ laptop Devices	Specifications: -Intel i5 processor, -12GB RAM, -NVIDIA 2GB VGA, -SSD, and Internet Network Connection.
b.	QGIS 3.16 Software	To process data sets into visual time series data
c.	Spreadsheet Software	To process data sets into graphs
d.	USGS Data sets	Earthquake center point data from 1900 to 2022 in the Cilacap area and surrounding areas as the main research data (https://www.usgs.gov)

2.3. Research Stages

The stages of this research are presented in the form of a flow diagram in Figure 2 below. The initial step of data acquisition is carried out by confirming the position of the spatial boundaries and the time span of the data set. Furthermore, spatial boundaries and time ranges will be input data in downloading the earthquake data set on the page https://earthquake.usgs.gov/earthquakes/search/. The data set is saved in (.csv) format. Data processing is divided into two stages of data import using different software. The process of importing .csv files into spatial vector data is carried out using QGIS software. The resulting vector data is point data for each record. Meanwhile, importing the file into spreadsheet software will produce a data set in table format.

Figure 2. Research Flow Diagram

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Spatial vector data will be visualized in the form of a Heatmap Map. Visualization in the form of graphs or heat maps aims to make fluctuations in the magnitude of earthquakes visible. Meanwhile, the earthquake data in the table is visualized into an earthquake data graph with time in years as the X axis and earthquake magnitude (Richter scale) as the Y axis. has been shown in Figure 1. The Heatmap map is converted into a time series based using the Temporal Controller Function. The results of the analysis show frames per year of the heatmap map in animated form, so that fluctuations in the magnitude of earthquakes can be seen at each spatial coordinate point. Meanwhile, graphic data will be analyzed with descriptive statistics to describe the data patterns formed.

3. RESULTS AND ANALYSIS

3.1. Data Processing

Data processing using QGIS software begins with importing CSV data. Next, the CSV data is converted into vector data in point form. Each point has latitude and longitude location information so that the spatial distribution of the data is presented in Figure 3 below. Spatial data was added with a base map overlay from Google Maps and vector data for Cilacap Regency in polygon form (Figure 4).

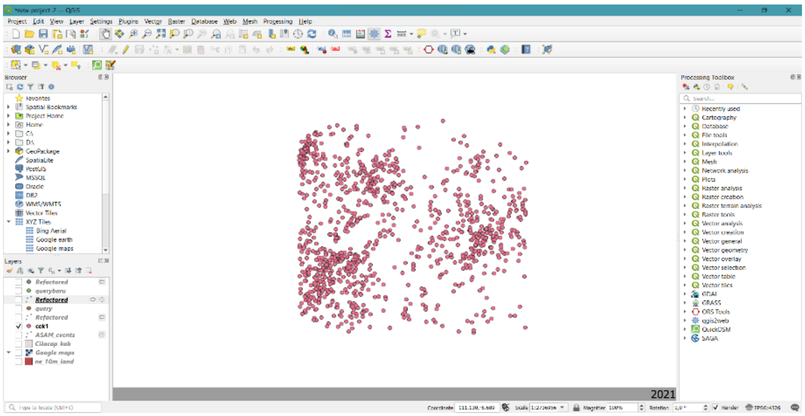

Figure 3. Data Point Display in QGIS Software

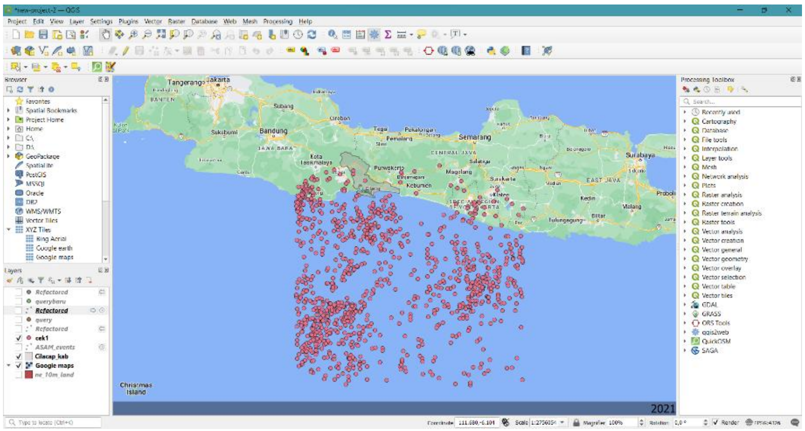

Figure 4. Overlay of Google Map Base Map and Cilacap Regency Polygon with Earthquake Data Points

Data processing with a spreadsheet using Microsoft Excel is carried out by importing data in CSV format with the resulting data distribution in table form. Next, attribute filtering is carried out with the final results being the attributes "time" and "mag". Time series graphs are created by taking the "time" attribute to indicate the time and the "mag" attribute to indicate the magnitude of the earthquake.

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3.2. Data Visualization

Spatial data in point form is then interpolated to see the data density based on location proximity. Interpolation is carried out using the Heatmap technique. This process is carried out using QGIS software with the visualization results shown in the following image.

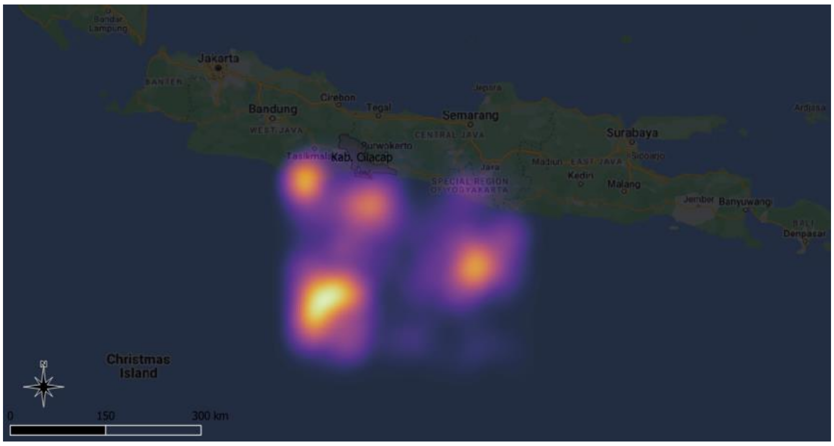

Figure 5. Interpolation results of earthquake data with Heatmap

Earthquake data in tabular form that has been filtered is then presented in line chart form in Figure 6. The data presented in line chart form shows the magnitude fluctuations of each event based on the time sequence of the event. It can be seen that most earthquakes have magnitudes in the range of 4 – 5 SR (Richter Scale). Some peak magnitudes are absent at certain time intervals. To determine the statistical characteristics of the data, descriptive statistical analysis was then carried out.

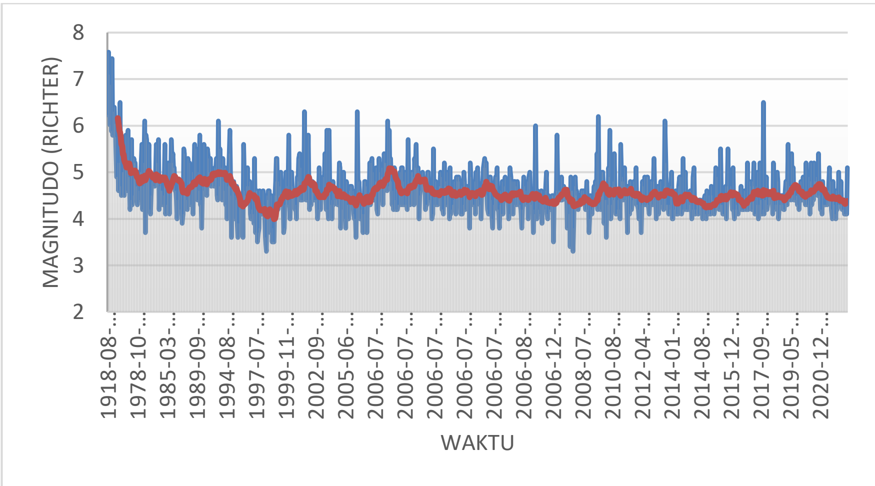

Figure 6. Earthquake Magnitude Time Series Graph

3.3. GIS Analysis

The results of spatial data visualization using the heatmap technique are then analyzed temporally using the Temporal function in QGIS software. The results of temporal analysis with frames per year produce 104 frames. Next, the 104 frames are sequenced into a video which is displayed at the following link https://youtu.be/m3B7HkfI8qY.

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Figure 7. Clip 4 frames of heatmap data visualization in time series (2018 - 2021)

The visualization of spatial data in the form of a heatmap (Figure 5) is compared with the visualization of spatial data in a time series in the video https://youtu.be/m3B7HkfI8qY with the clip in Figure 7 showing a different heatmap pattern. Visualizing earthquake data in a time series can show changes in earthquake magnitude density patterns and show changes in the geographic location of earthquake points from year to year.

3.4. Descriptive Statistical Analysis

The tabular data that has been presented in the line chart is then analyzed with descriptive statistics. The results of the descriptive statistical analysis are presented in Table 2. The average value (mean) of earthquake data around Cilacap in 1918 – 2021 is 4.58 SR. The highest value of 7.58 SR (Richter Scale) occurred on September 11 1921 at 04:01 with geographic coordinates -10.046˚ South Latitude 110.653˚ East Longitude. And the lowest value was 3.3 SR with two events, namely on January 27 2008 at 17:47 with geographic coordinates -8.793˚ South Latitude 108.373˚ East Longitude and May 5 1998 at 10:33 with geographic coordinates -10.243˚ South Latitude 109.714˚ BT.

Table 2. Descriptive statistical analysis of earthquake data

Descriptive Statistical Analysis	
Mean	4.587801
Standard Error	0.015697
Median	4.5
Mode	4.4
Standard Deviation	0.50206
Sample Variance	0.252064
Kurtosis	3.93269
Skewness	1.301576
Range	4.28
Minimum	3.3
Maximum	7.58
Sum	4693.32
Count	1023
Largest	7.58
Smallest	3.3
***Confidence Level* (95.0%)**	0.030802

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3.5. Discussion

Based on descriptive statistical analysis, it produces information on the mean and mode of earthquakes with almost the same values, as well as the largest and smallest magnitude values. GIS analysis by visualizing spatial data in a time series, apart from providing an overview of shifting trends in earthquake source locations, also provides a visual depiction of changes in earthquake magnitude density per year.

4. CONCLUSION

Based on the results of the analysis and discussion, this research produces the conclusion that :

1. The earthquakes around Cilacap in 1918 – 2021 had a magnitude ranging from 3.3 SR to 7.58 SR with a mean of 4.58 SR and a mode of 4.4 SR.
2. Visualization of earthquake data in a time series provides an overview of changes in trends in earthquake source locations and magnitudes from year to year.

5. ACKNOWLEDGEMENTS

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6. DECLARATION OF COMPETING INTEREST

We declare that we have no conflict of interest.

7. DAFTAR PUSTAKA

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