

## **Earthquakes time series visualization in cilacap earthquake zone using QGIS and USGS data sets**

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### **ABSTRACT**

Cilacap region earthquakes often occur with more than 5 Richter Scale. With these seismic conditions, earthquake studies in the Cilacap region will always be needed. These studies usually only have output in form of map visualization spatially, however, they have not been compiled in a time series. This study attempts to include visualization of spatial data in the form of a time-series. The data visualization was presented in form of graphs and maps. Graphical visualization using line bar graph type by applying descriptive statistics tries to determine the earthquake's magnitude fluctuation. The other visualization in form of Heatmap map analysis applying the Kernel Density method is interpolated earthquake magnitude spatial data. The data used in this research was retrieved from the USGS datasets between 1918 to 2021. The spatial boundaries were taken from  $-7.324^{\circ}\text{S}$ ,  $107.941^{\circ}\text{E}$  to  $-10.407^{\circ}\text{S}$ ,  $111.116^{\circ}\text{E}$ . The results of spatial data visualization using the heatmap techniques were then analyzed temporally using the Temporal function in the QGIS software. The results of temporal analysis within a year are then sequenced into a video which is displayed on the following link <https://youtu.be/m3B7Hkfl8qY>. The descriptive statistical analysis shows that Earthquakes have magnitudes ranging from 3.3 to 7.58 with a mean of 4.58 and a mode of 4.4. Heatmap analysis shows the results of earthquake magnitude interpolation with high density, located in the south of Cilacap and south of Yogyakarta. Also, the spatiotemporal analysis results show that there is a change in location trends that have high earthquake magnitude density values.

Keywords: Earthquake, QGIS, Time Series Visualization.

### **1. INTRODUCTION**

Earthquakes in the Cilacap region often occur with a magnitude more than 5 Richter Scale (SR), which is felt by residents, and with smaller magnitudes. BMKG said that the southern part of Java, especially the Cilacap region, is an area that always be alert for earthquake and tsunami threats because it has a dense population and is located on the southern coast of Java, which is directly facing the collision zone of the Indian Ocean plate and the Eurasian plate [1].

One of the earthquake research projects on the Cilacap region is risk and soil vulnerability analysis in 2016 and 2021. The 2016 Risk Analysis study stated that the entire city of Cilacap belongs to the medium hazard category, with the soil vulnerability level results was extent from high to low class [2]. Five years later, the BMKG research team analyzed the vulnerability of Cilacap city soil again, it concluded that the soil vulnerability in an area with a dense distribution of buildings and harder soil structures has a higher vulnerability [3]. Meanwhile, research on soil vulnerability in Adipala-the southern Cilacap district, stated that this area has high soil vulnerability [4]. These studies have the map spatial visualization output but have not been arranged in a *time-series manner*. So that it cannot explain descriptively the seismic fluctuations over time.

The geographical location of Cilacap Regency is shown in **Figure 1**. With the seismic conditions that have been mentioned before, earthquakes studies in the Cilacap region will always be needed for updating the latest conditions of its seismicity. Time Series Visualization is a study of changes in data



attributes and conditions from time to time, and also when the data change drastically, presented both statically and in animation methods [5].



**Figure 1** Cilacap district administrative boundaries map

Static views combine multi-views to show changes in both data trends and conditions. The animated views record the state of the data over a specified period in each frame or image and display them in chronological order.

Spatial data visualization time series can be performed using the Temporal Controller function in Quantum GIS (QGIS) and presented in the form of a Heatmap. The purpose of using a heatmap is that the data with the maximum value or the density data can be easily displayed [6], [7]. The Temporal Controller function is used to create a spatial distribution of heatmap data based on time series [8]. Spatial data visualization has now entered the era of spatiotemporal data, where data not only serve the information from the proximity of geographic points but also temporal data trends to see broader insights [9], [10]. It is hoped that by utilizing the Temporal Controller function and Heatmap visualization, the earthquake magnitude trend and distribution data in the Cilacap region can be seen over those years.

## 2. METHOD

### 2.1. Time and place

This research was conducted at the Informatics Engineering Study Program, Software, and Applied Computing Laboratory for 18 weeks. The dataset used in this study is the Earthquake data set for the Cilacap area from the USGS, from 1918 to 2021. The data set spatial boundaries extends from -7.324 °S, 107.941 °E to -10.407 °S, 111.116 °E.

### 2.2. Tools and materials

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

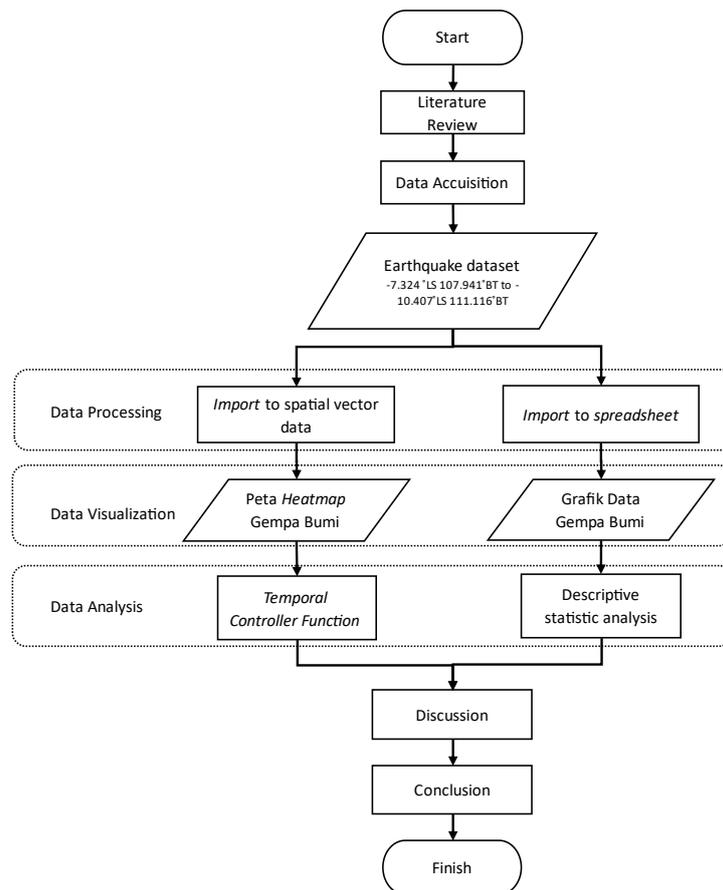
**Table 1** List of research tools and materials

No.	Names of Tools and Materials	Specifics Information
(1)	(2)	(3)
a.	Computer/Laptop	Specifications: - Intel i5 Processor, - 12GB RAM, - NVIDIA VGA 2GB, - SSDs, and - Internet Network Connection.
b.	QGIS 3.16 software	To process data sets into visual <i>time series data</i>

No.	Names of Tools and Materials	Specifics Information
c.	Spreadsheet Software	To process data sets into graphs
d.	USGS datasets	Earthquakes data from 1900 to 2022 for Cilacap region and its surroundings ( <a href="https://www.usgs.gov">https://www.usgs.gov</a> )

### 2.3. Research phase

The phases of this research are presented as a flowchart, shown in **Figure 2** below.



**Figure 2** Research flowchart

The initial step of data acquisition is carried out by ascertaining the position of the spatial boundary and the period of the data set. Furthermore, the spatial boundaries and time range were used as input for downloading the earthquake data sets from <https://earthquake.usgs.gov/earthquakes/search/page>. The data obtained from the dataset consists of earthquake's timetables, magnitudes, and geographic location coordinates (latitude and longitude) of the earthquake. Data sets were then stored in (.csv) format. Data processing was divided into two stages of data import using different software. The importing (.csv) files process into spatial vector data was done by QGIS software. The resulting vector data is in form of point data for each record. While importing files process to spreadsheet software will generate the data set in a tabular format.

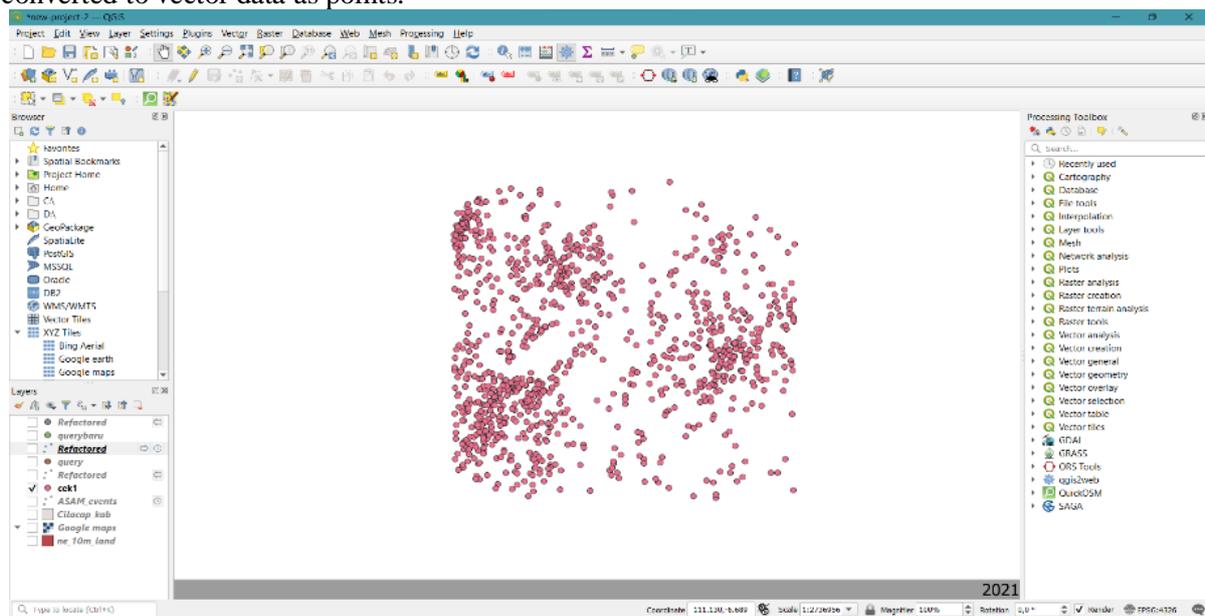
Spatial vector data will be visualized as a heatmap map. Visualization as graphs and heatmaps was intended to show the fluctuations in the earthquake's magnitude. The Heatmap technique used in this study is the Kernel Density method. This method will interpolate earthquake magnitude spatial data. The Kernel Density method is the most widely used interpolation method for heatmap interpolation. The principle of Kernel density is to calculate the density used to identify data distribution patterns in an area [11], [12]. While the earthquake data in the table was visualized as an earthquake graph. It has years unit as the X-axis and earthquake magnitude (Richter scale) as the Y-axis. Presentation of data in graphical form also uses the time series method to find historical series patterns [13]. GIS (Geographical

Information System) data analysis was carried out by viewing data based on geographic coordinates as shown in **Figure 1**. The Heatmap map was changed to be time series based using Spatiotemporal technique with 1-year event duration. The spatiotemporal technique provides an overview of fluctuations in spatial data patterns based on shifts in the event duration [14]. The results of the analysis were shown as heatmap frames per year which are animated so that the fluctuations in earthquake magnitude for each point of its spatial coordinates showed. While graphic data will be analyzed using descriptive statistics (data mean and data range) [15] to describe the pattern that had been formed.

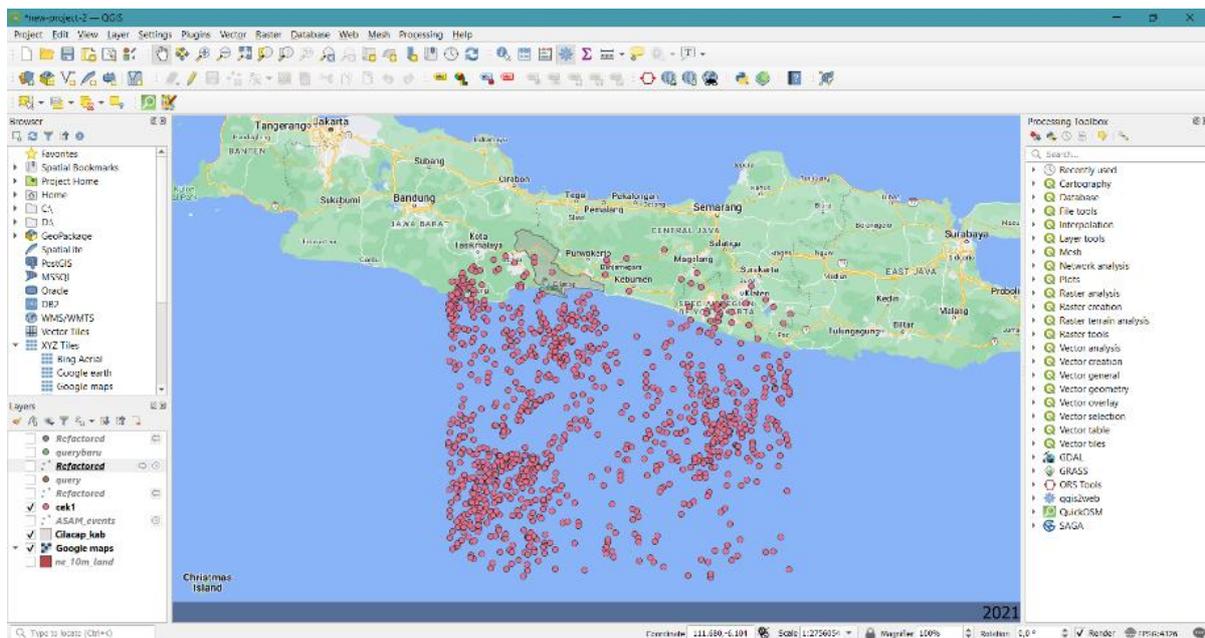
### 3. RESULTS AND DISCUSSION

#### 3.1. Data processing

Data processing using QGIS software begins with importing .csv data. Next, the .csv data was converted to vector data as points.



**Figure 3** Data points in QGIS software



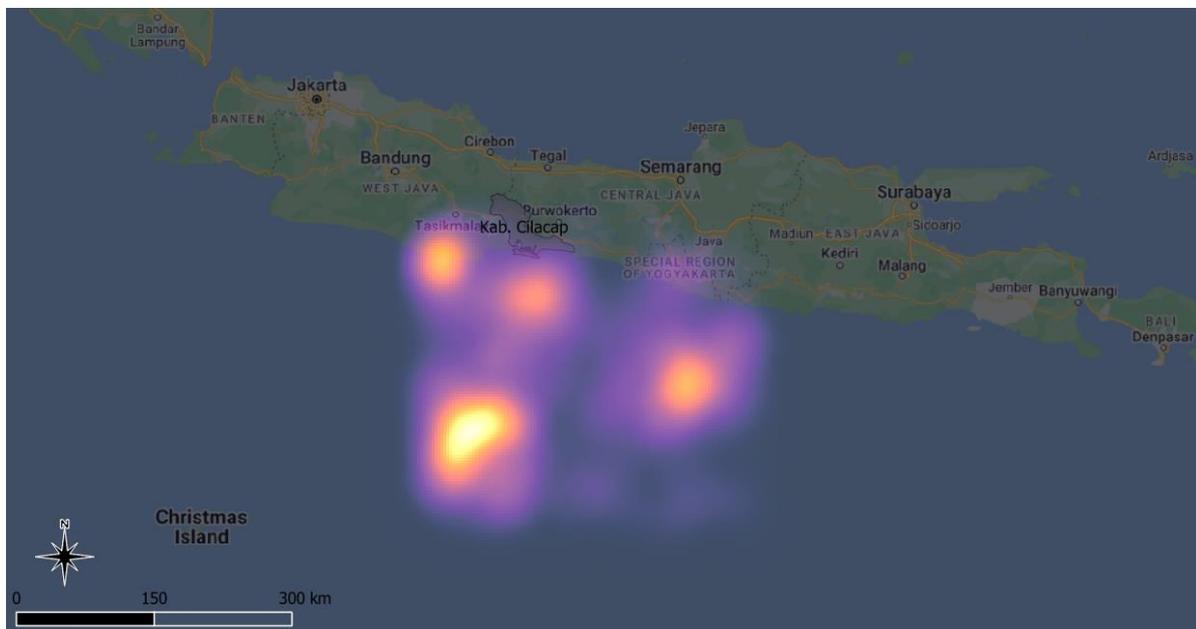
**Figure 4.** The overlay of the base map from Google Maps and Cilacap Regency Polygon combined with Earthquake point data

Each point has latitude and longitude location information so that the data distribution was displayed spatially as shown in **Figure 3** above. The spatial data was added to overlay the base map from Google Maps and the Cilacap Regency vector data as a polygon (**Figure 4**).

Data processing with tabular results is carried out using a spreadsheet from Microsoft Excel, through the CSV data import process. Next, attribute filtering was done using only "time" and "mag" attributes. The time series graphs are made by taking the "time" attribute to indicate time and the "mag" attribute to indicate earthquake magnitude.

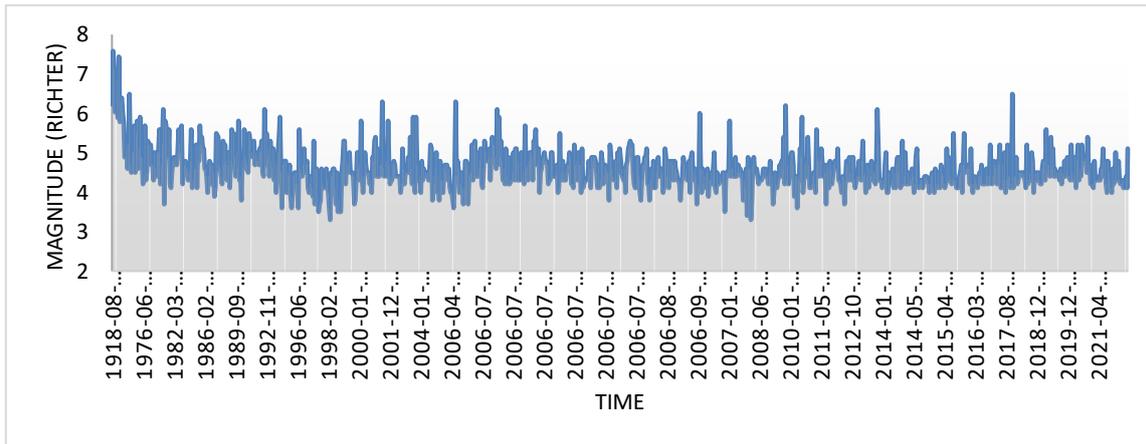
### 3.2. Data visualization

Earthquake spatial data has data attributes: magnitude, latitude and longitude, and the date of the earthquake. The heatmap visualization technique is in the form of a map using latitude and longitude attributes as geographic coordinates (X and Y axes), and magnitude as the Z axis. Values from the Z axis are interpolated using the heatmap technique with the Kernel Density method. Spatial data in form of points was then interpolated to indicate the density data based on the proximity of location. The interpolation was carried out using the Heatmap technique. This process is carried out using QGIS *software*. The visualization results are shown in **Figure 5** below.



**Figure 5** Earthquake interpolation data results using Heatmap

The color gradation from dark to light indicates the intensity of the earthquake magnitude is getting higher. **Figure 5** shows that there are 4 (four) heatmap points. Earthquake data in tabular form that has been *filtered* is then presented as a line chart, shown in Figure 6.



**Figure 6** Time series graph of earthquake magnitude

That line chart shows the magnitude fluctuation of each event based on the time sequence. It can be seen that most of the earthquakes have magnitudes within the 4–5 SR (Richter Scale) range. This chart shows some of the earthquake magnitude peaks at any given time interval. To find out the data characteristics statistically, then descriptive statistical analysis was carried out to provide an overview without making general conclusions [16].

### 3.3. Descriptive Analysis

The tabular data that has been presented in the line chart was then analyzed using descriptive statistics. The results are presented in **Table 2**. The average value (mean) of Cilacap earthquake data between 1918 – 2021 is 4.58 Richter scale. The highest value of 7.58 SR (Richter Scale) occurred on September 11, 1921, at 04:01 at  $-10.046^\circ$  South Latitude  $110.653^\circ$  East Longitude geographical coordinates. The lowest value, 3.3 SR occurs two times, January 27<sup>th</sup>, 2008, at 17:47 in  $-8.793^\circ$  South Latitude  $108.373^\circ$  East longitude and May 5<sup>th</sup>, 1998 at 10:33 in  $-10.243^\circ$  South Latitude  $109.714^\circ$  East Longitude geographic coordinates.

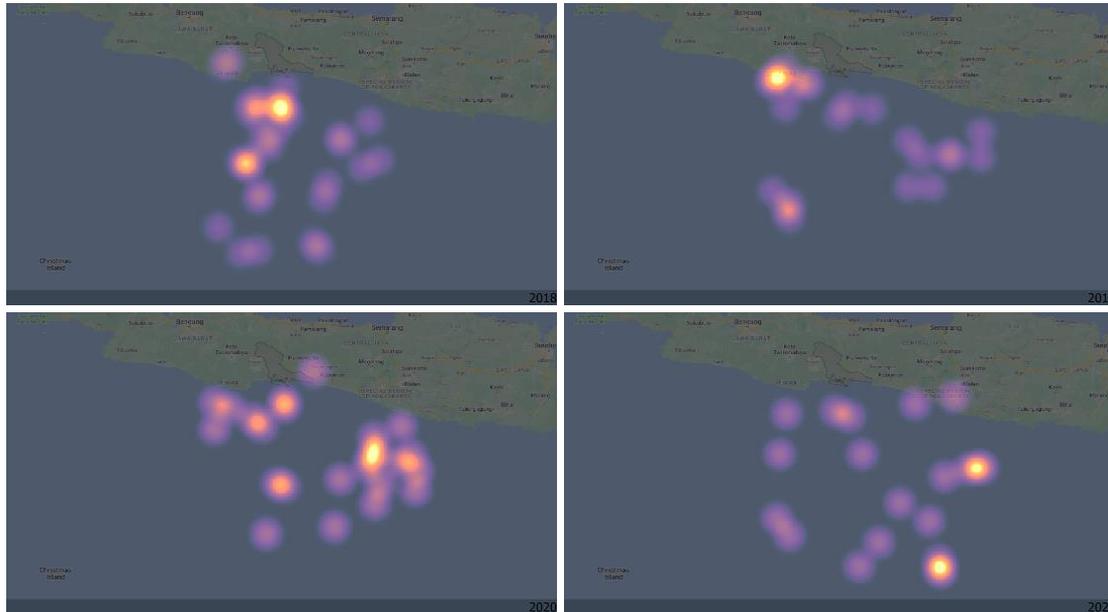
**Table 2** Descriptive analysis of the Cilacap’s earthquake data

Descriptive Analysis	
<i>Means</i>	4.587801
<i>Standard Error</i>	0.015697
<i>Median</i>	4.5
<i>Mode</i>	4.4
<i>Standard Deviations</i>	0.50206
<i>Sample Variance</i>	0.252064
<i>Kurtosis</i>	3.93269
<i>Skewness</i>	1.301576
<i>Range</i>	4.28
<i>Minimum</i>	3.3
<i>Maximum</i>	7.58
<i>Sum</i>	4693.32
<i>Count</i>	1023
<i>Largest</i>	7.58
<i>smallest</i>	3.3
<i>Confidence Level (95.0%)</i>	0.030802

### 3.4. GIS analysis

The results of spatial data visualization using the heatmap technique were then analyzed temporally using the Temporal function in the QGIS software. Those generate 104 frames based on frames data per

year. Then, the 104 *frames* were sequenced into a video, shown at the following link <https://youtu.be/m3B7Hkfl8qY>.



**Figure 7.** Heatmap data visualization for 4 clips in time series (2018-2021)

The spatial data visualization as a *heatmap* (**Figure 5**) is then compared with another visualization within the time range, as shown at <https://youtu.be/m3B7Hkfl8qY>, and **Figure 7** reveals the different patterns. It shows the earthquake magnitude density pattern changes and displays the earthquake's geographical location points changes over the years. **Figure 7** shows the heatmap map for 2018, 2019, 2020, and 2021 with earthquake points changes. From those example images, even though there is a shift in the location of the points, it can be seen that the heatmap points are definitely in the south of the Cilacap region and south of the Special Region of Yogyakarta (DIY).

### 3.5. Discussion

Descriptive analysis shows that the earthquake average value (mean) and the mode in the Cilacap region are the same, at the 4 Richter scale. This descriptive analysis also shows the occurrence of earthquakes in a certain pattern, especially at high magnitude values. GIS analysis using time series visualization, with the time series spatial data, provides an overview of shifting trends in earthquake source locations. It also provides a visual representation in earthquake magnitude density changes over the year. Figure 5 and 7 indicates the earthquakes heatmap. It shows the distribution of earthquake point positions. Earthquake points with a high magnitude have a higher brightness level. Based on this, a rough conclusion can be obtained that every year, there are some areas that have a high seismic value compared to others. This also could be compared with another frame years. With this, a rough picture of areas with a higher earthquake hazard can be obtained compared to others.

## 4. CONCLUSION

Based on the results, analysis, and discussion, this study concluded that Earthquakes around Cilacap in 1918 – 2021 have magnitudes ranging from 3.3 to 7.58 with a mean of 4.58 and a mode of 4.4. Heatmap analysis resulted in an interpolation of earthquake magnitudes indicating that high densities were found in locations south of Cilacap and south of Yogyakarta. The results of the spatiotemporal analysis show that there is a change in the trend of locations with high earthquake magnitude density values. Recommendations for further research development include: a) The results of data visualization are presented as a web-based system so that they can be easily disseminated to all parties who need this information; b) The event-duration and boundaries area can be varied based on specific theories and decision-making for specific analysis; c) More specific earthquake property analysis can be carried out as a further disaster mitigation effort.

### Thank-you note

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