Mapping Schools Vulnerability to Earthquakes: Case Study of Cianjur Earthquake 21 November 2022

Yani, Yani[1], *Mohamad* Tusam[1], *Dwi* Larasaty[1], and *Nur* Isnaini[1]

[1]Master of Geography Education, Universitas Pendidikan Indonesia, 40154 Bandung, Indonesia

Abstract. Earthquakes are unpredictable disasters that cause a lot of damage, such as the destruction of infrastructure and casualties. Indonesia has a high level of earthquake risk. One of the earthquakes that occurred was the Cianjur earthquake in November 2022, caused by the movement of the Cugenang fault. This earthquake caused many houses and public facilities, including schools, to be damaged. This study aims to map schools that are vulnerable to earthquakes as one of the early warning systems to improve disaster preparedness. The classification is based on the earthquake vulnerability map provided by BMKG. The research method used is Geographic Information System (GIS). Data from the earthquake hazard map and the distribution of schools were then analyzed using the overlay technique. From the results of this processing, three earthquake hazard zones were determined, namely the forbidden zone, the restricted zone, and the conditional zone. There are two schools with a percentage of 6.45% in the forbidden zone, seven schools with a percentage of 22.58% in the restricted zone, and 22 schools with a percentage of 70.97% in the conditional zone. More schools are in the conditional zone; therefore, it is necessary to increase earthquake disaster awareness.

Keyword: Earthquakes, Cugenang Fault, Schools, GIS.

1 Introduction

Occasionally, unexpected disasters, called earthquakes, hit around the world, causing significant damage to infrastructure and lives and injuries to the population [1]. The earthquake has resulted in a substantial economic impact and loss of life [2]. Indonesia has a higher level of earthquake risk than any other country in the world [3]. And the countries with the most seismic activity globally [4]. Located along the Pacific Ring of Fire, the region is where the three active tectonic plates of the Indo-Australian Plate, Eurasian Plate, and Pacific Plate meet, which has experienced several earthquakes. Earthquake threats can occur in single, sequential, or combined forms, depending on their source and effect [5].

Schools are facilities that play a role in meeting educational needs. Determining the location of school construction should consider the community's needs and the suitability of the area's characteristics [6, 14]. In November 2022, there was an earthquake with a

magnitude of 5.6 on the Richter scale in Cianjur [7, 15] that damaged 142 schools in three sub-districts, namely Cugenang, Cianjur, and Cilaku [8, 16] and caused ten teachers and 42 students to die, while seven teachers and 74 students were seriously injured. [9, 17]. The earthquake in Cianjur was an earthquake that did not originate from a subduction zone but from an active fault on land. According to a Meteorology Climatology and Geophysics Agency (BMKG) report, the earthquake was triggered by the Cugenang fault on the Rajamandala segment, with a southwest-to-northeast shear motion. Property damage to the school building is expected as it is located near the fault zone. Damage to buildings caused by earthquakes is the primary cause of the large number of casualties and property loss. [10, 18]. Schools are places where people gather at one time. As the number of school residents grows, the potential impact of earthquakes is expected to increase. Therefore, a fundamental disaster management step is identifying earthquake-prone schools. In this context, mapping schools that are prone to earthquakes becomes necessary.

Mapping schools vulnerable to earthquakes is one element of an early warning system to improve disaster preparedness. Meanwhile, schools are locations that tend to be affected by earthquakes, and children, especially school students, are among the most vulnerable groups to natural disasters [11, 19]. The significant impact of the Cianjur earthquake in the Cugenang sub-district has prompted previous research [6, 14] to assess the damage to primary schools in the area. However, the previous study did not consider junior and senior high school students. This research seeks to close that gap. It focuses on mapping the earthquake-prone schools in these schools. To achieve this goal, GIS was used to process and assign values to various layers of potentially earthquake-inducing themes to produce a map of the distribution of earthquake-prone schools in the Cugenang sub-district. GIS is a tool that facilitates data processing and analysis, both for short-term and long-term purposes [1]. This research contributes to the protection of high-risk groups in the school environment and supports authorities in taking preventive measures to reduce the impact of earthquakes.

2 Methodology

2.1 Study Area

Kecamatan Cugenang, located in Kabupaten Cianjur, West Java, became the research area. The coordinate position of Cugenang sub-district is 6°47'08.6"S 107°07'03.5"E. Administratively, the Cugenang sub-district is bordered to the north by the Pacet and Sukaresmi sub-districts, to the east by Cianjur and Mande sub-districts, to the south by Warungkondang sub-district, and the west by Sukabumi and Bogor districts. The region includes 16 villages, including Benjot, Cibeureum, Cibulakan, Cijedil, Cirumput, Galudra, Mangunkerta, Nyalindung, Padaluyu, Sarampad, Sukajaya, Sukamanah, Sukamulya, Talaga, Gasol, and Wangunjaya (Fig. 1).

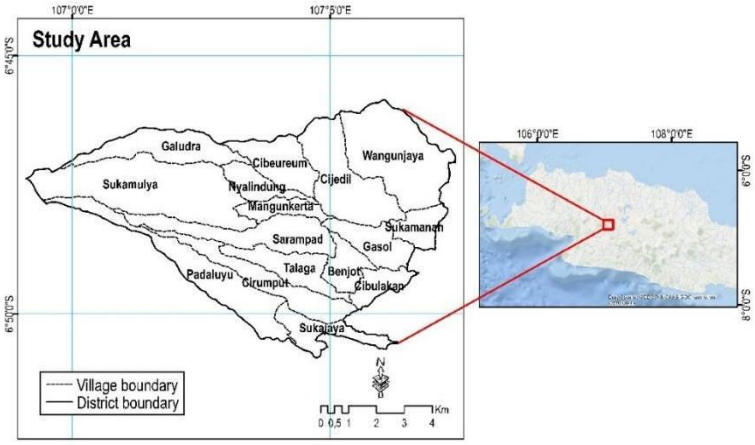

Figure 1. Study area

2.2 Data and Method

Schools in the study area are classified into highly vulnerable, vulnerable, and moderately vulnerable categories. The Classification is based on the Cianjur earthquake vulnerable map provided by Badan Meteorologi, Klimatologi, dan Geofisika (BMKG). The data obtained was converted into a vector model by georeferencing and digitizing in a GIS environment to produce an earthquake-vulnerable map layer. The primary data on the location of junior and senior high schools/vocational schools was collected through plotting on Google My Maps. The data was then extracted and classified based on the Cianjur earthquake hazard map. All data processing and analysis conducted utilized GIS overlay analysis tools (Fig. 2).

This study aims to assess and classify earthquake-hazard schools in Cugenang, Cianjur, including junior high schools (SMP), senior high schools (SMA), and vocational schools (SMK). The method used in this research is a Geographic Information System (GIS) with an overlay approach to analyze earthquake hazard data and school locations. The steps in this research include data collection, data processing, and GIS overlay analysis. The data collection process involved primary and secondary data collection. Primary data on school locations was collected through Google My Maps.

Meanwhile, secondary data was obtained from earthquake hazard maps provided by the Meteorology, Climatology, and Geophysics Agency (BMKG). Data processing was conducted using GIS software. First, the earthquake hazard map from BMKG was georeferenced to align it with real-world coordinates. This step is essential to ensure spatial accuracy. Next, the digitization method converted the earthquake hazard map into vector format. School location data was then extracted from Google My Maps.

Data analysis was conducted using an overlay operation to overlap school locations on the hazard map. This operation allowed the integration of different layers of data. Next, it assessed which schools fell into each hazard category. Classification was then conducted based on the school's position within the earthquake hazard zone. The classification process categorized the schools into three hazard levels: highly vulnerable, vulnerable, and moderately vulnerable.

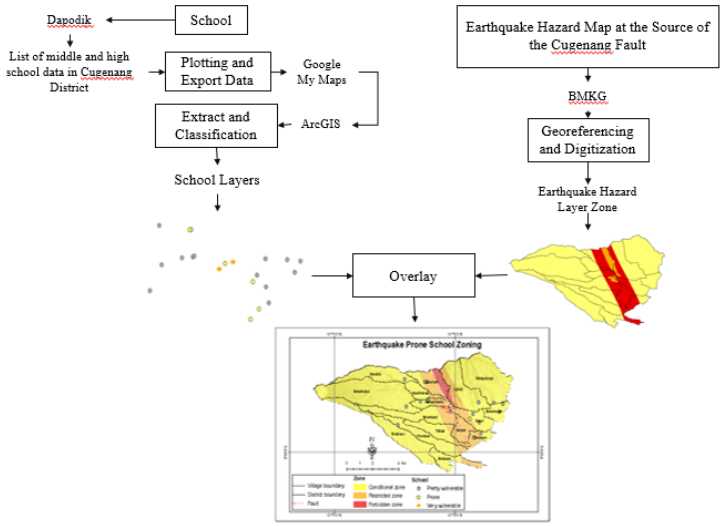

Figure 2. Conceptual framework

3 Results

3.1 Distribution of Schools in Cugenang

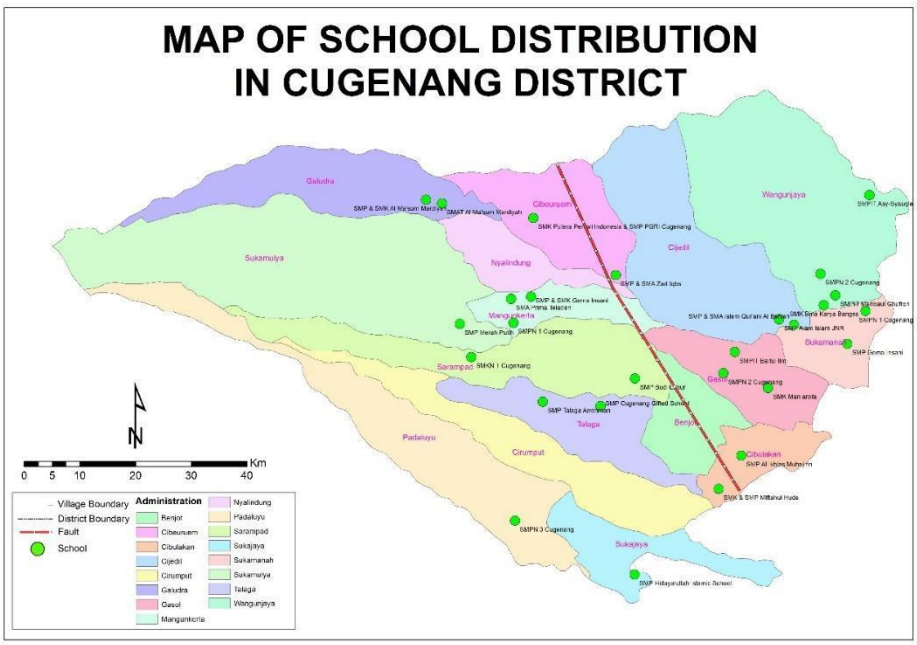

Figure 3. School Distribution

There are 31 schools, including junior high schools, senior high schools, and vocational schools in Cugenang district, which are unevenly distributed. Some villages than three schools, but there are some junior high schools, senior high schools, or vocational schools.

The following is the data on junior high schools, high schools, and vocational schools in Cugenang district.

Table 1. School in Cugenang District

No	District	School	Total
1	Benjot	-	0
2	Cibeureum	SMP PGRI Cugenang, SMP Zad Iqbs, SMA Zad Iqbs, SMK Putera Pertiwi Indonesia	2
3	Cibulakan	SMP Islam Miftahul Huda, SMP Al Ikhlas Muhajirin, SMK Miftahul Huda	3
4	Cijedil	SMP Alam Islam Jnr, SMP Islam Qurani Al Bahjah, SMA Islam Qurani Al-Bahjah Cianjur	3
5	Cirumput	-	0
6	Galudra	SMP Al Ma'shum Mardiyah, SMPT Terpadu Al Ma'shum Mardiyah, SMAT Al Ma'sum Mardiyah, SMK Al Ma`sum Mardiyah	4
7	Gasol	SMPIT Baitul Ilmi, SMK Man Arofa	2
8	Mangunkerta	SMPN 1 Cugenang, SMP Gema Insani, SMA Prima Teladan, SMK Gema Insani	4
9	Nyalindung	-	0
10	Padaluyu	SMPN 3 Cugenang	1
11	Sarampad	SMP Budi Luhur, Smk Negeri 1 Cugenang	2
12	Sukajaya	SMP Hidayatullah Islamic School	1
13	Sukamanah	-	0
14	Sukamulya	SMP Merah Putih	1
15	Talaga	SMP Cugenang Gifted School, SMP Talaga Arrohman	2
16	Wangunjaya	SMPN 2 Cugenang, SMPIT Manbaul Ghufron, SMK Bina Karya Bangsa, SMPIT Asy-Syauqie	4
Total			31

Based on this table, the villages in Kecamatan Cugenang without a junior high school, senior high school, or vocational school are Benjot Village, Cirumput Village, Nyalindung Village, and Sukamah Village. The villages with four schools are Gasol Village, Mangunkerta Village, and Wangunjaya Village.

3.2 Earthquake Vulnerability Map in Cugenang District

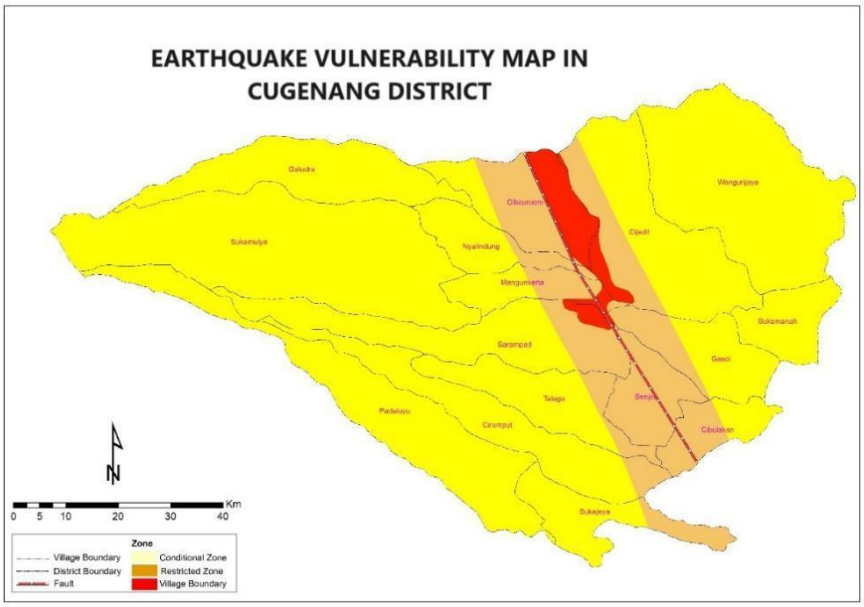

Figure 4. Earthquake Vulnerability Map in Cugenang

The aftermath of the earthquake in Cugenang Sub-district remains uncertain. This is because the fault pattern exhibited a different segmentation than nearby faults. Further investigations by the Geological Agency revealed that the movement of a new fault triggered the earthquake, the Cugenang Fault, which is oriented at N 347° E. This fault passes through six villages in the Cugenang Sub-district: Cibeureum, Nyalindung, Mangunkerta, Sarampad, Cibulakan, and Benjot. It runs through two villages in Pacet Sub-district, Ciherang and Ciputri, ending in Nagrak Village, Cianjur Sub-district. The fault has a slope of 82.8 degrees and exhibits a dextral strike-slip movement mechanism.

The Cugenang Fault structure runs from north to south, and the area along its path has suffered significant damage. The primary causes of the earthquakes in Cugenang Sub-district are the active Cugenang Fault, which is a newly identified geological feature, the weak composition of the local rocks, and the shallow location of the epicenter, which results in stronger vibrations even with a magnitude of 5.6 [12]

Cibeureum village is an area with high vulnerability in the forbidden zone in the east, limited in the center, and part of the area in the west is in the limited zone. Meanwhile, parts of Mengunkerta, Seremped, Gasol, Benjot, Cibulakan, and Cimulya villages are restricted. Generally, villages far from the fault, such as Warungjaya village in the east and Sukamulya village in the west, have relatively low vulnerability.

3.3 Mapping Schools Prone to Earthquakes

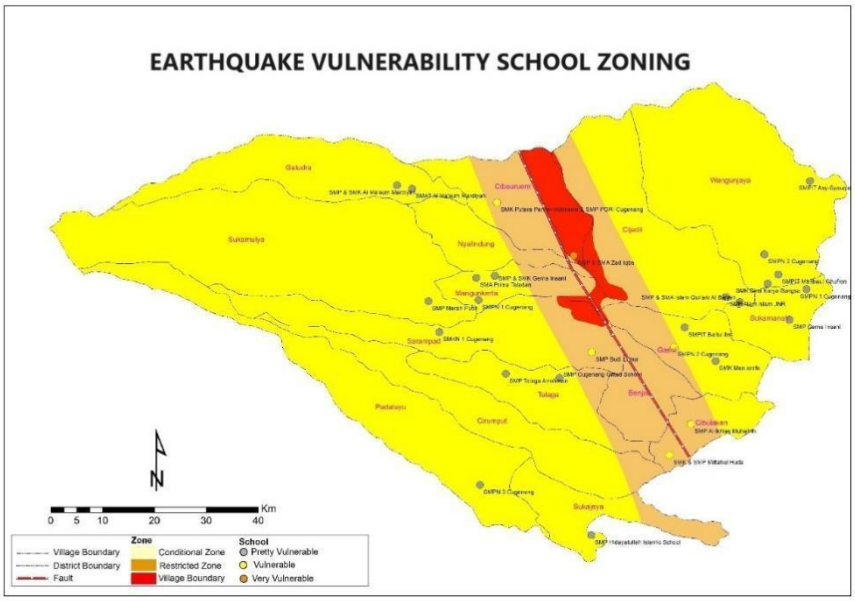

Figure 5. Earthquake Prone School Zoning

The characteristics of the area where the school is located determine the school's level of vulnerability. Schools at the highly vulnerable level are located close to the Cugenang fault, which has characteristics that make them susceptible to deflation and landslides.

The overlay analysis results show that 6.45%, or 2 out of 31 schools, Zad Iqbs Junior and Senior High School, are at the Very Vulnerable level.

Seven schools, or 22.58%, are at the Vulnerable level: SMK Miftahul Huda, SMK Putera Pertiwi Indonesia, SMP Al Ikhlas Muhajirin, SMP Budi Luhur, SMP Miftahul Huda, SMP PGRI Cugenang, and SMPN 2 Cugenang.

There are 22 schools or 70.97% of the schools in the Pretty Vulnerable category, namely SMA Islam Qur'an Al Bahjah, SMA Prima Teladan, SMAT Al Ma'sum Mardiyah, SMK Al Ma'sum Mardiyah, SMK Bina Karya Bangsa, SMK Gema Insani, SMK Man Arofa, SMKN 1 Cugenang, SMP Al Ma'sum Mardiyah, SMP Alam Islam JNR, SMP Cugenang Gifted School, SMP Gema Insani, SMP Gema Insani, SMP Hidayatullah Islamic School, SMP Islam Qur'an Al Bahjah, SMP Merah Putih, SMP Talaga Arrohman, SMPIT Asy-Syauqie, SMPIT Baitul Ilmi, SMPIT Manbaul Ghufron, SMPN 1 Cugenang, and SMPN 3 Cugenang.

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Table 2. Earthquake Prone School Zoning

No	Category	School's Category	School	Total	%
1	Forbidden	Very Vulnerable	SMA Zad Iqbs	2	6.45%
			SMP Zad Iqbs		
2	Restricted	Vulnerable	SMK Miftahul Huda	7	2258%
			SMK Putera Pertiwi Indonesia		

			SMP Al Ikhlas Muhajirin		
			SMP Budi Luhur		
			SMP Miftahul Huda		
			SMP PGRI Cugenang		
			SMPN 2 Cugenang		
3	Conditional	Pretty Vulnerable	SMA Islam Qur'ani Al Bahjah	22	70.97%
			SMA Prima Teladan		
			SMAT Al Ma'sum Mardiyah		
			SMK Al Ma'sum Mardiyah		
			SMK Bina Karya Bangsa		
			SMK Gema Insani		
			SMK Man arofa		
			SMKN 1 Cugenang		
			SMP Al Ma'sum Mardiyah		
			SMP Alam Islam JNR		
			SMP Cugenang Gifted School		
			SMP Gema Insani		
			SMP Gema Insani		
			SMP Hidayatullah Islamic School		
			SMP Islam Qur'ani Al Bahjah		
			SMP Merah Putih		
			SMP Talaga Arrohman		
			SMPIT Asy-Syauqie		
			SMPIT Baitul Ilmi		
			SMPIT Manbaul Ghufron		
			SMPN 1 Cugenang		
			SMPN 3 Cugenang		
Total				**31**	**100%**

4 Discussion

The GIS processing of fault distance and school point data resulted in three earthquake hazard zones: forbidden, restricted, and conditional. The forbidden zone, marked in red on the map, is most affected by earthquake shaking because it is located at a very close distance with a range of 0-10 meters. Approximately 61.9% of all Cugenang sub-district schools are in this zone. 28.6% of the restricted zone is marked with orange shading on the map, where this zone is located along the Cugenang Fault from 10 meters to 1 kilometer. The conditional zone has a percentage of 9.5% of the total schools; this zone has a lower degree of vulnerability and is more than 1 kilometer from the fault zone. The dominance of earthquake hazard zoning is at the level of the restricted zone, so it needs particular review and treatment

to minimize the impact. Given that schools are an essential tool in developing a nation, hidden threats are lurking in the safety of children.

5 Conclusion

The Cugenang Fault structure is elongated from north to south, and along the alignment of the fault line, there is an area of high damage. The main factor of earthquake causation in the Cugenang Sub-district is the active Cugenang Fault as a newly identified geological structure. Earthquake vulnerability in Cugenang Sub-district can be divided into three categories: moderately, vulnerable, and highly vulnerable. Based on the overlay of the earthquake-prone map in Cugenang Sub-district with the distribution of secondary schools (both junior high schools, high schools, and vocational schools), it can be seen that two schools are at the very vulnerable level, six schools are at the vulnerable level, and 13 schools are in the moderately vulnerable category.

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