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Assessment of Social Vulnerability and Post-Earthquake Affected Areas in Sumedang Regency

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ABSTRACT

This research aims to map social vulnerabilities and affected areas after the earthquake in Sumedang Regency. Social vulnerability was mapped using scoring adapted from the Regulation of the Chairman of the National Disaster Management Agency number 2 of 2012 which researchers modified according to existing data in 2024. Social vulnerability data is population density, sex ratio, vulnerable age group ratio, population ratio poor and disabled population ratio. The affected areas were mapped using field surveys and visualized using Geographic Information System (GIS) software. However, previous studies have not yet integrated dynamic post-disaster social changes or validated the vulnerability classifications with real-time community resilience indicators. Based on research, it was found that Sumedang Regency has 11 sub-districts including high classification, 8 sub-districts with medium classification and 7 sub-districts with low classification. The high classification of social vulnerability is in the central urban area of Sumedang Regency and the southern area bordering Bandung Regency. The survey results show that an area with a radius of 2 km is a very vulnerable area, a radius of 4 km is vulnerable and 6 km is medium. Based on the results of the analysis, it was found that areas with high social vulnerability and those affected by earthquakes were very vulnerable, namely North Sumedang District, Cisarua District, Cimalaka District and Ganeas District.

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Introduction

Social vulnerability refers to conditions in which individuals or groups are vulnerable to environmental pressure, challenges, or danger. Social vulnerability is a parameter in disaster risk studies, because people with certain social conditions are vulnerable to being

affected by disasters (Mantika, et al. 2020). Social vulnerability is important to be carried out as a disaster mitigation effort. Social vulnerability to disasters refers to the level of vulnerability of a person, group, or community to the impacts caused by natural disasters (Flanagan, et al. 2011) or human-related disasters (Nugraha, et al. 2022). Groups with are in lower economic conditions or have limited access to resources may be more vulnerable to disasters because they may not the same access to protection, evacuation, or recovery services (Yoon. 2012).

Earthquake are a natural disaster that have a major impact on social vulnerability. Areas located in earthquake zones have a higher risk of earthquakes (Rahman, et al. 2023). The level of vulnerability can vary depending on the frequency and magnitude of earthquake in the region (Alizadeh, et al. 2018). Based on the Regulation of the Head of the Indonesian National Disaster Management Agency (BNPB) No. 2 of 2012, social vulnerability consists of population density and vulnerable groups (Maulidin, et al. 2022). Vulnerable groups consist of the sex ratio, vulnerable age group, poor population ratio and disabled population ratio (Pahleviannur, et al. 2023). Social vulnerability is an important aspect of the study of minimizing the risk of earthquake disasters (Fordham, et al., 2013).

Sumedang Regency just experienced an earthquake disaster on December 31 2023. This condition was triggered by an active fault located in the Sumedang Regency. The earthquake occurred three times at different times. Based on data from the Center for Volcanology and Geological Disaster Mitigation (PVMBG) and the Meteorology, Climatology and Geophysics Agency (BMKG), there are four earthquake epicenter points in the central urban area of Sumedang Regency. The urban area of Sumedang Regency has area with a large population therefore, mapping social vulnerabilities is necessary. Urban areas in Sumedang Regency are zones prone to earthquakes caused by active faults.

Social vulnerability mapping and affected areas can be mapped using Geographic Information System (GIS) software, with several predetermined parameters and algorithms (Frigerio, et al. 2016). GIS technology can be used to monitor environmental conditions and identify patterns that can indicate possible areas affected by an earthquake disaster (Thiri, 2017). Social vulnerability parameters such as population density, sex ratio, vulnerable age groups, poor population ratio and disabled population ratio can be mapped administratively using GIS. Map products can be basic capital in mitigating earthquake disasters in term of social vulnerability (Yariyan, et al. 2020). BNPB has special calculations for the parameters for composing and scoring social vulnerability (Naryanto. 2020), so it will be more comprehensive if carried out in GIS software with the data that provided, then follow based on National Disaster Management Agency Regulation No. 2 of 2012.

Social vulnerability is an important part of assessing earthquake disaster risk, because it directly impacts society (Fatemi, et al. 2017). Social vulnerability to earthquakes can be assessed using survey methods directed toward community social data (Malthuf, 2023). Social vulnerability can be mapped in relation to community capacity in deal with earthquake disasters (Maulidin, et al., 2023). Urban areas vulnerable earthquake and a direct impact on society (Schmidtlein, et al. 2011). Other research has mapped social vulnerability using the Analytic Hierarchy Process (AHP) approach, and then mapped it administratively (Guo, et al. 2020). This study utilizes GIS to map social vulnerability based on the National Disaster Management Agency regulations combined with the actual situation.

This study aimed to map social vulnerability and affected areas after the earthquake in Sumedang Regency. The mapping in this study was used to compare social vulnerabilities with affected areas, so that the map results would be more specific and significant. Social vulnerability maps and affected areas provide comprehensive information for disaster mitigation efforts. This research will be useful for studying earthquake disasters using GIS in terms of social aspects and affected areas. The results of mapping social vulnerabilities and

affected areas can be used to develop appropriate mitigation strategies to reduce the risk of earthquake disasters in the Sumedang Regency.

Methodology

Research on social vulnerability and areas affected by earthquakes was conducted in Sumedang Regency, West Java. This location was chosen because an earthquake caused by an active fault impacted on the surrounding community and buildings. The social vulnerability parameters were adapted from the 2016 National Disaster Management Agency (BNPB) inasrisk, namely population density, sex ratio, vulnerable age group ratio, poor population ratio and disabled population ratio (Sutedjo, 2020). Each parameter has a weight that has been set in the BNPB inarisk as described in Table 1.

Table 1. Weight of Social Vulnerability

Parameter	*Weight*	*Classification*		
		Low	*Medium*	*High*
Population density (60%)	*60*	*195 - 783 km2*	*783.1 - 1513 km2*	*1513.1 - 3740 km2*
Vulnerable groups				
Sex Ratio (10%)		*0.97 - 0.98*	*0.981 - 1.02*	*1.021 - 1.06*
Percentage of vulnerable age groups (10%)	*40*	*40.12% - 45.45%*	*45.46% - 48.27%*	*48.28% - 53.13%*
Percentage of poor people (10%)		*9% - 10%*	*10.1% - 13%*	*13.1% - 18%*
Disabled population ratio (10%)		*93 - 332*	*331.1 - 623*	*623.1 - 1342*

Source: Regulatory chief BNPB No.2 in 2012, modified in 2024

The affected areas were identified using field survey methods. The survey sample was carried out incidentally, according to the area affected both physically by buildings and by earthquake vibrations. This research was conducted using incidental sampling, because the building damage was spread according to the impact of the earthquake, and was uncertain, so samples were taken incidentally in the field, according to actual conditions. A survey was conducted to look at the condition of the building and interview respondents regarding the earthquake incident. Survey results are analyzed using a buffer with a radius appropriate to the affected area, this technique is conducted, based on damage to areas caused by earthquakes. The affected area will be compared with the magnitude of the earthquake and the structure that was the source of the earthquake. Magnitude and structure data were adapted from the Meteorology, Climatology and Geophysics Agency (BMKG) and the Center for Volcanology and Geological Disaster Mitigation (PVMBG). The next stage is an overlay technique carried out on social vulnerability products and affected areas. This product is processed using GIS technology, which is capable of spatially mapping objects such as vulnerability zones and affected earthquakes (Girasole, et al. 2017).

Result and Discussion

Social Vulnerability is studied using the parameters of population density, disabled people, sex ratio, percentage of poverty, and percentage of vulnerable ages. Based on the analysis, it was found that Jatinangor District is the most populous district with a residence of 3740 residents per square kilometer, while the lowest density is located in Jatigede District with a residence of 195 residents per square kilometer. Jatinagor District borders Bandung Regency and has several facilities that support people to live. This sub-district is an area with quite large economic activity, so many people live there. Jatigede District borders Majalengka Regency, this area is an area where there are very few settlements. Jatigede sub-district is included in the development area, here there is a dam that has just been inaugurated, namely the Jatigede dam, even though it is a sub-district with a low population

density, it is possible that in the next few years the population will increase, due to infrastructure development.

Population density is divided into three classifications with 4 sub-districts classified as high, 6 sub-districts classified as medium and 16 sub-districts classified as low (Figure 2). The denser the population, the more vulnerable the community is to be affected by earthquake hazards, so that 6 sub-districts have high vulnerability, one of which is North Sumedang Sub-district which is close to the source of the earthquake. Based on Sumedang open data, the total number of disabled people in Sumedang Regency is 12,420. People with disabilities include the physically disabled, mentally disabled, people with mental disorders, physical disabilities, blind, deaf and speech impaired. Data states that Situraja District has the most people with disabilities, namely 1342 people, while the lowest is in Surian District with 277 people. The results of the spatial analysis are divided into three classifications, namely 6 sub-districts are high classification, 9 sub-districts are medium classification and 11 sub-districts are low classification. The more people with disabilities, the more vulnerable they are to earthquake disasters, especially people with physical disabilities and the blind who are limited in evacuating.

The sex ratio in Sumedang Regency is almost evenly distributed. The sex ratio range is 0.97 to 1.06. In theory, this condition is quite safe when faced with social vulnerability in the gender ratio aspect. In this study, the sex ratio was divided into three classifications, according to available data and the need for scoring analysis in social vulnerability mapping. Based on the results of the analysis, it was found that 5 sub-districts were in high areas, 12 sub-districts were in the medium classification, and 9 sub-districts were in low areas. The smaller the sex ratio value, the more vulnerable it is to earthquakes. The percentage of poverty in Sumedang Regency ranges between 9% to 18%. The percentage of poverty is divided into three classes according to the data, namely 9 sub-districts are high, 4 sub-districts are medium and 13 sub-districts are low. The greater the percentage of poverty, the more vulnerable it is to earthquake disasters.

The vulnerable age group in this study is the population aged 0-14 and 65+, while those aged 15 to 64 are not vulnerable, so the calculation of the percentage of vulnerable age is the number of ages 0-14 and 65+ divided by the total population in each sub-district. Based on the analysis results, it was found that the smallest percentage was 40.12% and the largest was 53.13%. The greater the percentage value, the more vulnerable it is to earthquake disasters. The percentage classification of vulnerable age is divided into three classes, namely 4 high classification sub-districts, 13 medium classification sub-districts and 9 low classification sub-districts. A large percentage is in the northern area of Sumedang Regency, which has rural characteristics, so those of productive age tend to migrate, rather than stay.

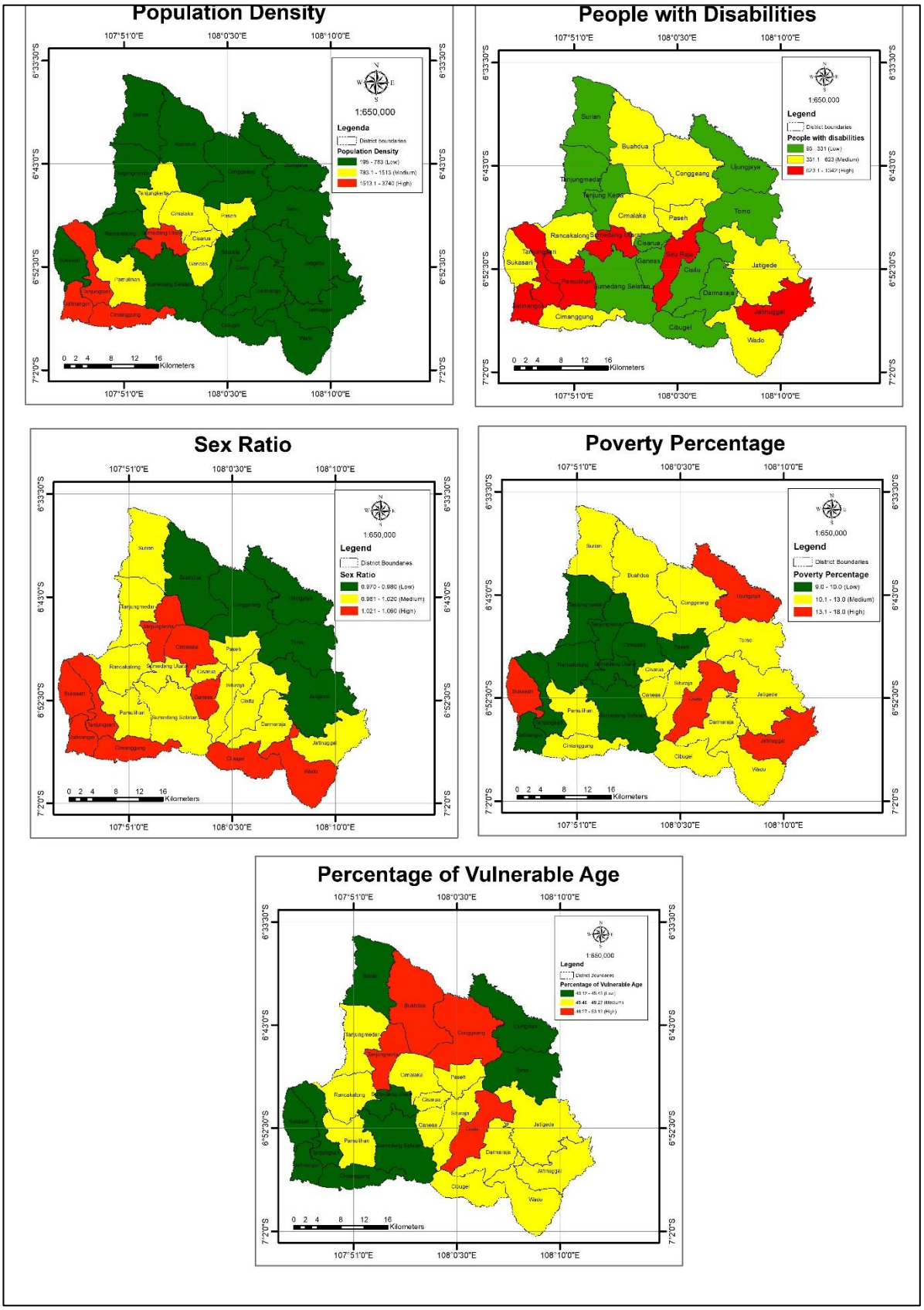

Figure 1. Variable Map (Year processing results 2024)

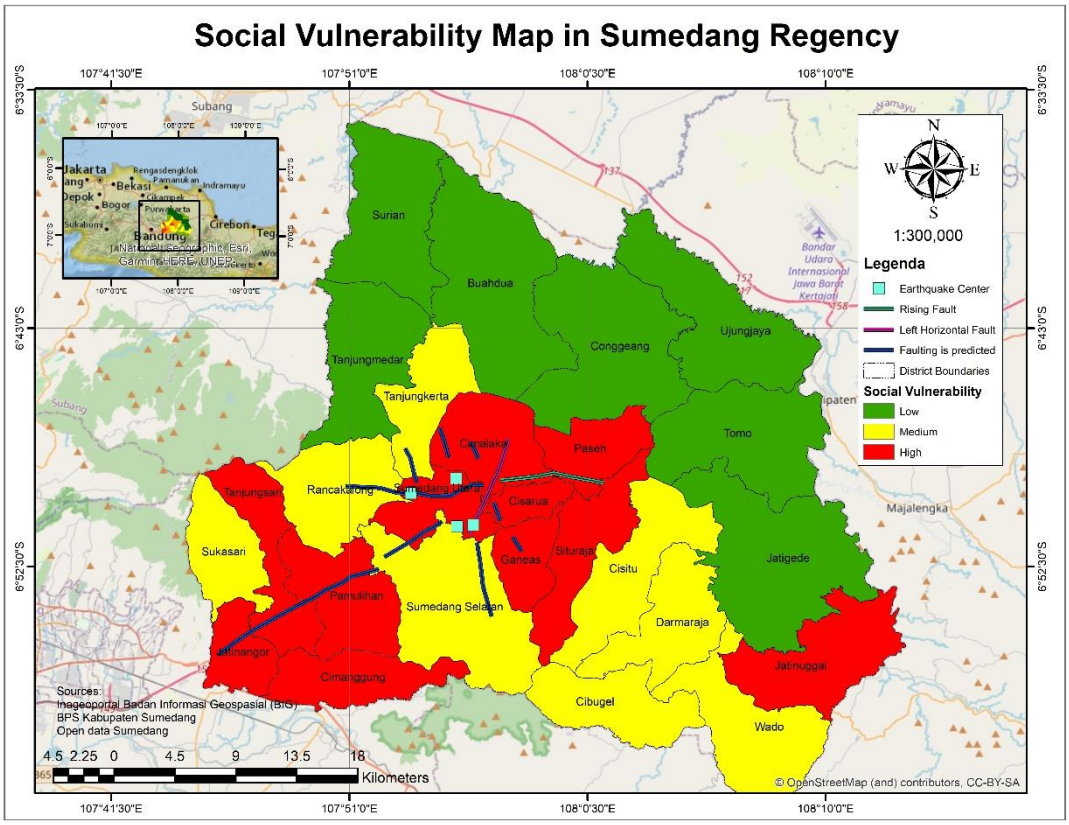

Figure 2. Social vulnerability Map (Year processing results 2024)

The results of the social vulnerability analysis show that Sumedang Regency has 11 sub-districts including high classification, 8 sub-districts with medium classification and 7 sub-districts with low classification (Figure 3). The high classification of social vulnerability is in the central urban area of Sumedang Regency and the southern area which borders Bandung Regency. High classification areas are areas with urban community characteristics, which have high economic activity and complete infrastructure facilities. Medium classification is spread across the west, east and southeast areas. Spatially, it is very logical that the distribution of population mobility is spread from rural to urban areas. The low classification is spread in the northern area of Sumedang Regency which borders Majalengka Regency and Subang Regency. This area is a sparsely settled area, tending to be forests, gardens and rice fields. This area has rural characteristics. From the social vulnerability map, it can be concluded that geographical conditions have an impact on social vulnerability for earthquake disasters, because the more vulnerable the more people are affected. Areas close to faults and located in urban areas are areas that are very vulnerable to earthquakes

Affected areas

The affected area in this research is the physical buildings taken in the area around the fault and the epicenter of the earthquake. Based on PVMBG and BMKG data, there were 4 earthquake centers, which were in North Sumedang District. This area is close to several faults identified by PVMBG and BMKG. Based on information, there are faults that triggered the earthquake, namely the Tanjungsari Sumedang fault and the Cipeles fault. The closer to the epicenter the greater the vibration, the first earthquake didn't last very long, the second earthquake wavered like there was an increase and decrease. The level of damage depends on the type of building, on average the buildings affected are (1) houses that are 20 years old, (2) houses with no building structure (no building bones/concrete), (3) houses located on landfill

sites. , (4) houses near the banks of the Cipeles river, (5) buildings along Jalan Prabu Geusan Ulun, and (6) buildings that are really close to the epicenter of the earthquake. The survey results show that the 2 km radius area is a very vulnerable area, the 4 km radius is vulnerable and the 6 km radius is medium (figure 4). The 2 km radius was adjusted to reflect the condition of buildings affected by the earthquake, including damage and ground shaking felt by residents. Field results indicate that 2 km is a severely affected distance.

The radius map of the earthquake-affected area is juxtaposed or overlaid with the social vulnerability map so that sub-districts that are considered high vulnerability and affected by the earthquake will appear. Based on the results of the analysis, it was found that areas with high vulnerability and very vulnerable impacts were North Sumedang District, Cisarua District, Cimalaka District and Ganeas District. The nearest sub-districts in the affected zone are included in moderate social vulnerability, but are included in the very vulnerable affected zone, namely parts of South Sumedang District, parts of Rancakalong District and parts of Tanjung Kerta District. North Sumedang subdistrict is an area that needs attention, because it has high social vulnerability and is a very highly impacted area.

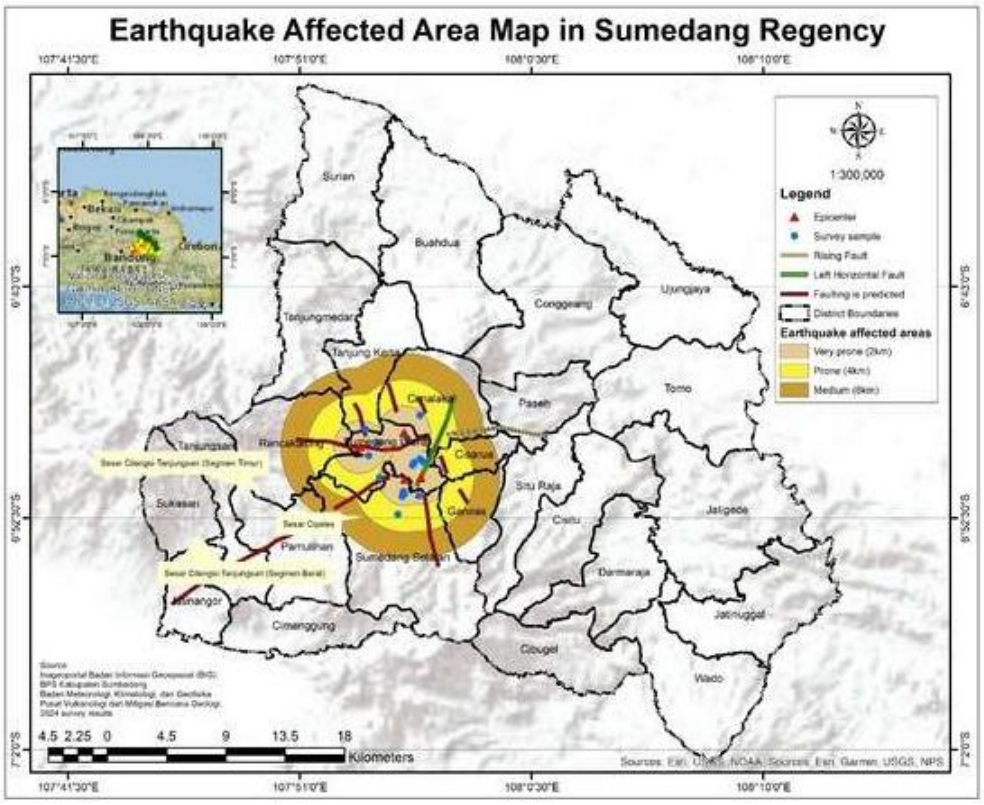

Figure 3. Earthquake Affected Map (Year processing results 2024)

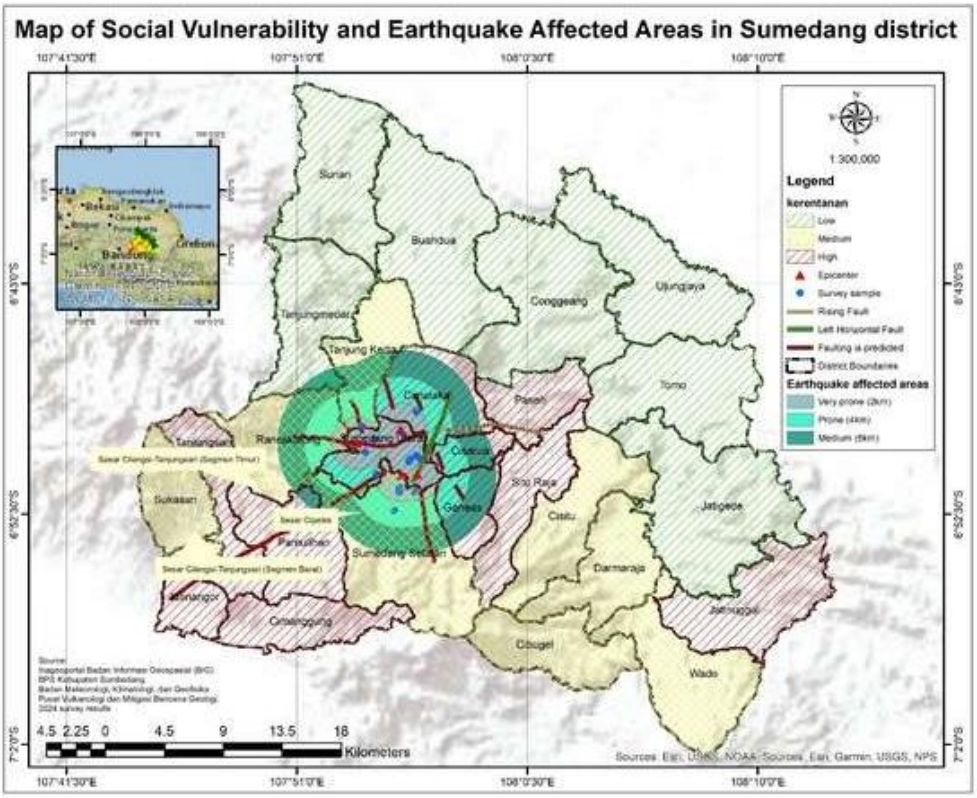

Figure 4. Social Vulnerability Map and Earthquake-Affected (processing results 2024).

Conclusion

Social vulnerability in Sumedang Regency was studied using the parameters of population density, people with disabilities, sex ratio, percentage of poverty, and percentage of vulnerable age group. The analysis shows that Jatinangor District is the most populous district with 3740 residents per square kilometer, while the lowest density is in Jatigede District with 195 residents per square kilometer. The north Sumedang District has high vulnerability because it is close to the earthquake source and has a high population density. The number of people with disabilities in Sumedang Regency is 12,420 people, with Situraja District having the highest number and Surian District having the lowest number. The sex ratio in Sumedang Regency is almost equal. The poverty percentage ranged from 9% to 18%. Vulnerable age groups included people aged 0-14 years and 65 years and > 65 years. A large percentage is in the northern area of Sumedang Regency, which has rural characteristics, so those of productive age tend to migrate, rather than stay.

The results of the social vulnerability analysis show that Sumedang Regency has 11 and 7 sub-districts in the high, medium and low classification respectively. North Sumedang District and its surroundings were included in the high classification, while sub-districts in the northern area of Sumedang Regency are included in the low classification. In this study, the area affected by the earthquake was around the fault and epicenter which was located in the North Sumedang District. The affected earthquake radius with the very vulnerable, vunerable and vunerable moderate were 4 km and 6 km, respectively. This condition is indicated by the condition of the affected buildings at the research site. The radius map of the earthquake-affected area was compared with the social vulnerability map. The results show that areas that are highly vulnerable and highly vulnerable are some areas in North Sumedang, Cisarua, Cimalaka and Ganeas subdistricts. The sub-district closest to the affected zone was included in the moderate social vulnerability category, but was also included in the highly vulnerable affected zone. This condition depends on the social characteristics of the

sub-district, based on the vulnerability formula calculation in the National Disaster Management Agency regulations. North Sumedang District requires special attention because it has high social vulnerability and a very high level of impact.

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Conflict of Interest

The author declares that there is no conflict of interest regarding the research titled "Assessment of Social Vulnerability and Post-Earthquake Affected Areas in Sumedang Regency".

Data Availability

The data that support the findings of this study are not publicly available due to ethical restrictions concerning participant confidentiality. However, data are available from the corresponding author upon reasonable request

Author Contributions

All authors contributed equally to the conceptualization, writing, and critical revision of the manuscript. All authors read and approved the final manuscript

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