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Analysis of susceptible disaster region based on the peak ground acceleration and earthquake intensity in Mamasa 2018

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Abstract. This study aims to know the susceptible disaster region based on peak ground acceleration and earthquake intensity on earthquake study cases in Mamasa 2018. Data that is used in this research is data on earthquake cases in Mamasa 2018 that is gained from the Indonesian Agency for Meteorology, Climatology, and Geophysics (BMKG) district IV Makassar, it included data of the time when the earthquake happened, latitude (S), longitudinal (E), depth (< 60 km) and magnitude (≥ 5) SR. The calculation of on peak ground acceleration was conducted by using Donovan and Mc.Guirre methods, whereas to calculate the value of intensity, it is using the Wald method (1999). The result from the calculation of on peak ground acceleration by Donovan is 95.903 gal to 377.094 gals with the intensity VI to VIII MMI. Whereas the calculation result of on peak ground acceleration by Mc.Guirre method is 58.981 gal to 227.39 gals with the intensity V to VII MMI. MMI intensity of the Wald method is obtained by using the PGA value conversation Mc.Guirre method that is closer to the intensity of the result of the macroseismic survey in Mamasa District and relates with the damage that happened on location. The mapping of earthquake intensity based on PGA Mc.Guirre method shows that 3 (three) sub-districts that have an intensity of VII MMI, namely Tawalian Sub-district, Mamasa Sub-district, and Sesean Padang Sub-district. The area is the most vulnerable. Mamasa has low-risk level from the earthquake, although sometimes an earthquake happened until now. This result is supported by a geological map in the Mamasa regions that showed source rock in that area is a type of hard rock that consist of granitic materials.

1. Introduction

West Sulawesi region is an earthquake zone from the expansion of the seabed in Makassar Strait. Seismotectonic activity in this area is also caused by faults on land including the Saddang Fault, the Kalukku Fault, and in the eastern part of this area, there is the Palu Koro fault. Seismicity activity in this area is dominated by shallow earthquakes (depth less than 60 km) and medium earthquakes (depths between 60-300 km) [1]. An earthquake rocked Mamasa Regency and its surroundings on November 6, 2018, at 02:35:53 WITA. The earthquake mechanism based on BMKG calculations is a strike-slip fault. Until November 21, 2018, at 06:00:00 WITA, BMKG has recorded 721 earthquakes of various magnitudes and 240 earthquakes of which were felt by the people [2].

The Saddang fault line appears to cross from the coast of Mamuju, West Sulawesi, cutting diagonally across the central part of South Sulawesi. To the southern part of South Sulawesi, it is



continued by the Walanae fault. In Mamasa, the crossing of the Saddang Fault runs northwest-southeast. In this segment, successive earthquakes occurred. Based on the mechanism, in this segment, the Saddang Fault is a horizontal strike-slip fault. The results of the analysis of the source mechanism of several significant earthquakes that occurred in Mamasa show that there is a similarity in the instrument, namely a horizontal fault (strike-slip) with a left movement. So it stands to reason that the current increase in earthquake activity in Mamasa is related to the Saddang Fault activity [3].

One of the essential things in seismological research is knowing the damage caused by earthquake vibrations to buildings. It is necessary to adjust the strength of the building to be built in the area [4]. The peak ground acceleration value is required to make the building design earthquake resistant. The amount of peak ground acceleration (PGA) is the most prone area to earthquake hazards [5]. The peak ground acceleration value obtained can be used to determine the magnitude of the earthquake intensity value (level of vulnerability) experienced by the place. Damage to buildings and facilities caused by the earthquake is determined by the intensity parameter (MMI), which correlates with the thickness of the sediment [6]. Although strong earthquakes did not occur frequently, they are very endangered human life [7]. There is a concentration of the population here. Hence earthquakes often cause loss of property and social life [8]. Therefore, a study is needed to find the peak ground acceleration value and the intensity caused by the earthquake.

2. Method

2.1 Materials

The data used in this study is the 2018 Mamasa earthquake data obtained from Makassar Region IV Meteorology, Climatology and Geophysics Agency including data on earthquake event time, latitude (S), longitude (E), depth (<60 km), and magnitude (≥ 5 SR).

2.2 Data analysis

2.2.1 Creating a grid. Creating grids with intervals of $0.25^\circ \times 0.25^\circ$ at locations 2.725 South Latitude - 3.1 South Latitude and 119.05 East Longitude - 119.575 East Longitude.

2.2.2 Calculating distances hypocentre. Hypocenter distance is calculated by equation (1)

$$R = \sqrt{\Delta^2 + h^2} \quad (1)$$

Where:

R = hypocenter distance (km)

Δ = epicenter distance (km)

h = depth distance (km)

2.2.3 Calculating the value of the maximum ground acceleration. The calculation of the value of the peak ground acceleration is done using the Donovan and Mc. Guirre.

Donovan [9].

$$a = \frac{1800 \exp^{0.5M}}{(R + 25)^{1.32}} \quad (2)$$

Where a is the ground acceleration (gal), M is the magnitude (SR), and r is the hypocenter distance in km.

Mc. Guirre (1997) equation [10].

$$E_v = \alpha 10^{bM} (R + 25)^{-c} \quad (3)$$

Where E_v = eventuality of acceleration (gal), alpha (α) is a constant of 472, b is 0.278, and c is 1.301. While M = magnitude (SR), and R = distance of hypocentre (km). The depth of the earthquake being input from 9 and 70 km but was greater at 10 km. This empiric is more efficient for an earthquake with a strength of 6.5, and hypocentre not more than 50 km.

2.2.4 Calculating the MMI intensity value. Earthquake MMI intensity calculations were carried out using the Wald (1999) equation with the PGA conversion of Donovan and Mc. Guirre. David J. Wald et al. (1999) [10].

$$I_{MM} = 3.66 \log PGA - 1.66 \quad (4)$$

Where I_{MM} is the MMI intensity, and PGA (gal) is the acceleration value that had been obtained in the research area.

2.2.5 Create a map of the peak ground acceleration and intensity map. Make a map of the peak ground acceleration by the Donovan and Mc. Guirre and the earthquake MMI intensity map of the Donovan and Mc. Guirre.

3. Results and Discussion

3.1 Results of research

Earthquake-prone areas based on the map of the peak ground acceleration (PGA) and earthquake intensity in Mamasa Regency are described as follows:

3.1.1 Maximum land acceleration in Mamasa District. The peak ground acceleration value using the Donovan and Mc. Guirre method in 14 sub-districts in Mamasa district is shown in table 1. The peak ground acceleration value of the Donovan method is higher than the Mc. Guirre method.

Table 1. The maximum ground acceleration values in 14 sub-districts in Mamasa

Sub-district	Grid		Maximum Ground Acceleration (gal)	
	East longitude	South latitude	Donovan	Mc.Guirre
Tawalian	119.45	-2,925	377,094	227,390
Mamasa	119,425	-2,875	298,276	180,470
Sesean Padang	119,425	-3,025	285,236	172,691
Tanduk Kalua	119.35	-3,075	207,557	126,238
Pana	119,525	-3,075	209,816	127,593
Tabang	119,525	-2,825	215,929	131,256
Balla	119,325	-2,975	232,073	140,922
Rantebulahan Timur	119,225	-2,975	165,431	100,946
Bambang	119.25	-2,925	178,968	109,083
Buntu Malangka	119.2	-2.85	148,521	90,768
Kemahalaan	119,175	-3,075	134,972	82,601
Aralle	119,075	-2,875	111,429	68,382
Mambi	119,125	-3	125,636	76,967
Tabulahan	119.05	-2,725	95,903	58,981

Table 1 shows that based on the Donovan method and the Mc. Guirre, the region that has the maximum peak ground acceleration value, namely Tawalian sub-district which is at the coordinates 2,925 S, 119,450 E, with the peak ground acceleration value of the Donovan method, namely 377.094 gals and the Mc. Guirre is 277.39 gals. Then Mamasa Subdistrict at coordinates 2,875 S and 119,425 E

with the peak ground acceleration value of the Donovan method of 298,276 gals and the Mc. Guirre process of 180,470 gals. And Sesean Padang District at coordinates 3.025 S and 119.425 E with the peak ground acceleration value of the Donovan method of 285,236 gals and the Mc. Guirre process of 172,691 gals.

3.1.2 Earthquake intensity in Mamasa Regency. The MMI intensity is based on the PGA conversion of Donovan and Mc. Guirre will be compared with the results of the macroseismic survey in Table 3.

Table 2. The Intensity of MMI Earthquake in Mamasa in 14 sub-districts in Mamasa Regency

Sub-district	Grid		MMI intensity based on PGA:	
	East longitude	South latitude	Donovan	Mc.Guirre
Tawalian	119.45	-2,925	VIII	VII
Mamasa	119,425	-2,875	VII	VII
Sesean Padang	119,425	-3,025	VII	VII
Tanduk Kalua	119.35	-3,075	VII	VI
Pana	119,525	-3,075	VII	VI
Tabang	119,525	-2,825	VII	VI
Balla	119,325	-2,975	VII	VI
Rantebulahan Timur	119,225	-2,975	VI	VI
Bambang	119.25	-2,925	VII	VI
Buntu Malangka	119.2	-2.85	VI	VI
Kemahalaan	119,175	-3,075	VI	V
Aralle	119,075	-2,875	VI	V
Mambi	119,125	-3	VI	V
Tabulahan	119.05	-2,725	VI	V

Table 2 shows that the MMI intensity scale of Mamasa District PGA conversion from Donovan and Mc Guirre is almost the same in several districts. As for those whose scales differ, they are only one scale different. The coordinate of Tawalian Subdistrict is 2.925 S, 119.450 E is an area that has the maximum MMI intensity value with the PGA Donovan conversion is VIII MMI and the PGA Mc. Guirre conversion is VII MMI. While the area that has the minimum MMI intensity value is Tabulahan at 2,725 S coordinates, 119.05 E, Mambi at coordinates 3 S, 119.125 E, Aralle at coordinates 2.875 S, 119.075 E and Kemahalaan at coordinates 3.075 S, 119.175 E with the MMI intensity value of the PGA Donovan conversion is VI MMI, and the PGA Mc.Guirre conversion is V MMI.

Table 3 shows the Mamasa MMI intensity on a scale of III MMI to IV MMI. It means that the MMI intensity scale of the Mamasa area based on the macroseismic survey is lower than the empirical equation using the Donovan and Mc. Guirre Method. Based on table 3 and table 2, the MMI intensity scale of the Mc.Guirre method is closer to the MMI intensity scale based on a macroseismic survey in the Mamasa Regency area.

Table 3. Earthquake MMI intensity based on the macroseismic survey in Mamasa [2]

Point	Latitude	Longitude	MMI	Location
1	295,683	11,939,298	IV	Tondok Ampo Village
2	295,849	11,938,686	IV	Tawalian District Office
3	291,203	11,942,289	IV	Lambanan Village
4	290,051	11,942,162	IV	Imanuel Church in Lambanan Village
5	294,278	11,938,090	IV	SMTK Mamasa Kel. Mamasa
6	294,595	11,937,994	IV	Tatoa Village
7	294,324	11,937,882	IV	Behind the mayor's office Regent of Pato'longan hamlet
8	294,138	11,937,531	IV	Jl. Mamasa development
9	294,314	11,937,440	IV	Jl. Development Ex. Mamasa
10	294,185	11,937,765	IV	Mamasa Health Center
11	293,961	11,937,867	IV	New village
12	293,701	11,937,898	IV	Sato Petrus church, Buntu Buda village
13	293,958	11,937,769	IV	Banua Mamase Hospital
14	294,277	11,937,650	IV	Tatoa Village Kel. Tawalian
15	293,989	11,937,556	IV	Buntu Buda Village
16	293,941	11,937,390	IV	Bamba Buntu, Buntu Buda village
17	293,712	11,937,360	III	Dead end village (Maissong)
18	293,653	11,937,533	IV	BTM Church, Buntu Buda
19	293,408	11,937,888	IV	Batu Village
20	293,350	11,938,079	IV	Tusan Village, Tondok Bakaru
21	299,951	11,933,481	IV	Kondosapata General Hospital
22	296,678	11,937,609	III	Rantedambu Hamlet, Rantetonga Village
23	295,202	11,940,105	III	Dusun Buntu Rea Kel. Tawalian Kec. Tawalian
24	293,364	11,938,855	IV	Litak Sakka
25	291,130	19,937,837	IV	SDK 016 Hamlet Rante Pongko Kec. Mamasa
26	292,761	11,935,130	III	Taupe Village, Kec. Mamasa

3.1.3 Map of peak ground acceleration and earthquake intensity in Mamasa District

3.1.3.1 *Peak ground acceleration map.* Figure 1 shows that based on the Donovan method the areas that have the maximum peak ground acceleration value are Tawalian District, Mamasa District, and Sesean Padang District.

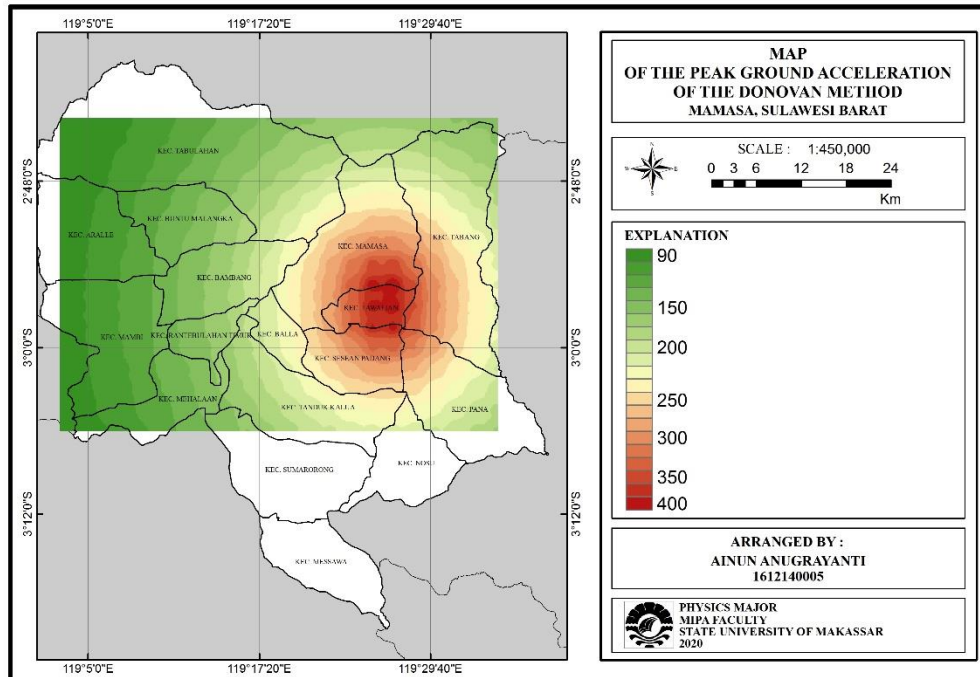


Figure 1. The Donovan method of peak ground acceleration map

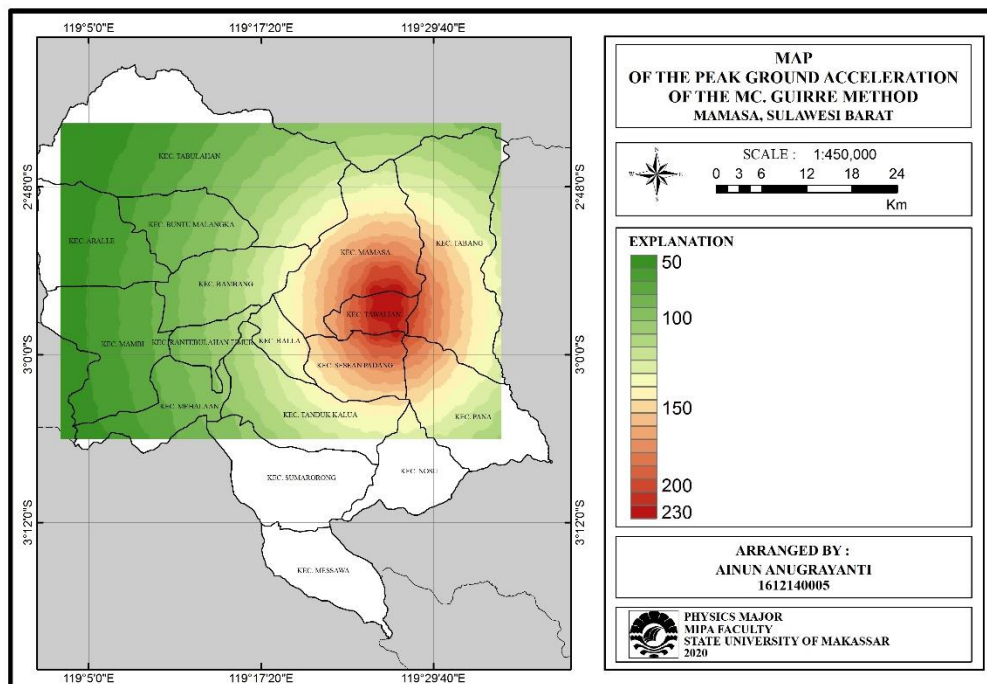


Figure 2. Map of the peak ground acceleration of the Mc. Guirre method

Figure 2 shows that based on the Mc. Guirre areas that have the maximum peak ground acceleration value are Tawalian District, Mamasa District, and Sesean Padang District which are marked with red color on the map.

3.1.3.2 Earthquake intensity map

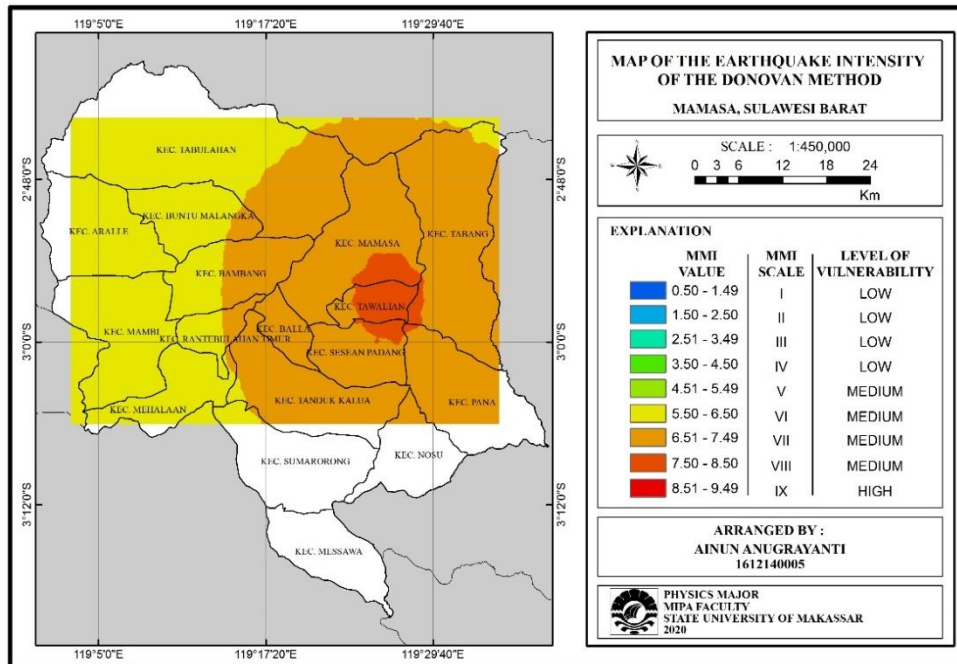


Figure 3. Wald intensity map with the Donovan PGA conversion method

Based on Figure 3 shows the intensity value which was obtained from the PGA conversion using the Donovan method, which is VI to VIII MMI marked with the colour on the map, namely yellow to dark orange. The area that has the maximum intensity, namely VIII MMI, is the Tawalian District.

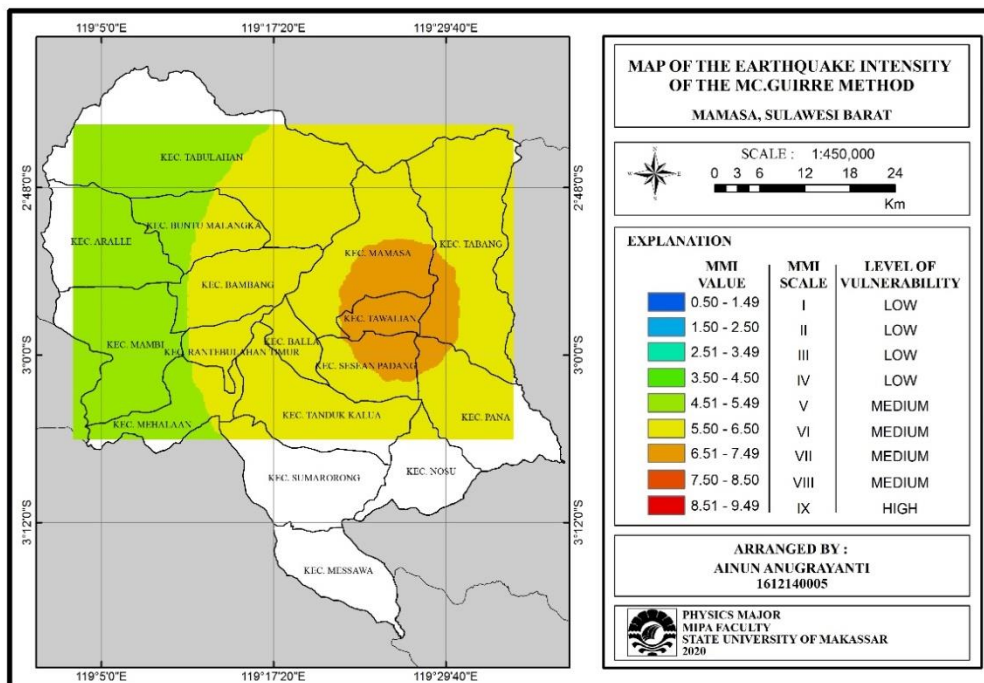


Figure 4. Wald intensity map by conversion Mc.Guirre's PGA method

Figure 4 shows the intensity value of the PGA conversion method MC. Guirre (1977), which is V to VII with green to orange colour. The areas that have the maximum intensity of VII MMI are Tawalian, Mamasa, and Sesean Padang District.

3.2 Discussion

Mamasa earthquake is categorized as a Swarm type earthquake where the earthquake occurs with regular frequency, but it is dominated by earthquakes with small magnitudes [2]. Areas with a more excellent peak ground acceleration value (PGA) can be more vulnerable than areas with smaller ground acceleration values. The largest PGA was near the earthquake source [11].

From the mapping made based on the Donovan method and the Mc, Guirre in general, the sub-districts in Mamasa Regency that have the highest peak ground acceleration are Tawalian, Mamasa, and Sesean Padang. The factor that causes the high value of acceleration in this area is the frequency of earthquakes with large magnitudes in this relatively high area, which is thought due to the activity of the Saddang Fault, known as an active fault. So it is natural that this fault is in the phase of accumulation and it is time to release the energy which is manifested as continuous earthquake activity.

Based on Table 2 and Table 3, it can be seen that the MMI intensity scale of the Wald method with the conversion of the peak ground acceleration of the Mc. Guirre way is closer to the intensity scale of the macroseismic survey results in Mamasa when compared to the MMI intensity scale of the Wald method with the peak ground acceleration conversion of the Donovan method. It indicates that the Mc.Guirre way is more suitable for estimating the peak ground acceleration in Mamasa Regency. The Mc.Guirre is more acceptable than other empirical equations because the PGA value corresponds to the Indonesian PGA region [12] and the magnitude of the MMI intensity corresponds to the damage in the field. It shows that the Mamasa area still has a low level of danger risk from earthquake shocks, even though until now, the occurrence of earthquakes is still ongoing. This result is supported by a geological map in the Mamasa area which shows that the source rock in that area is a type of hard rock that consists of Granitic material [2].

The greater the land movement, the greater the intensity or risk felt by the local community [13]. Based on the intensity value described above, the calculation results obtained are not precisely the same as the macroseismic survey results in Mamasa shown in table 3 but are quite close even though the results of calculations using the empirical method are of more excellent value. However, results it can be used to build more earthquake-resistant in anticipation of preventing damage to buildings. There is a discrepancy between the results obtained and the results shown in the macroseismic survey.

4. Conclusion

Peak ground acceleration (PGA) value using the Donovan method (95,903 gal-377,094 gals) is higher than using the Mc. Guirre way (58,981 gal-227.39 gals) so the calculation results of the Donovan method can be used to build earthquake-resistant in anticipation to prevent them from occurring damage to buildings. The scale of the MMI intensity of the Wald method (V - VII MMI) was obtained by using the Mc. Guirre PGA value conversion is closer to the intensity Scale of the macroseismic survey results in Mamasa Regency. From the earthquake intensity mapping based on the PGA Mc. Guirre shows that three districts have a high level of vulnerability, namely VII MMI, including Tawalian, Mamasa, and Sesean Padang.

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