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Determining Seismicity Using the Likelihood Method in Sumbawa Island Region Period 1972-2022

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Abstract: Research has been carried out regarding determining seismicity in the Sumbawa Island area for the period 1972-2022. Seismicity is seismic activity or the number of earthquakes in a certain period of time. The research was carried out with the aim of determining the level of rock fragility, seismic activity, and earthquake return period with an observation area boundary of 116.5° – 119.3° East Longitude and 10° – 8° South Latitude. The research was carried out at the Center for Meteorology, Climatology and Geophysics Region III Denpasar using the likelihood method for seismicity level M ≥ 3 and depth ≤ 30 km. Determining the level of rock fragility as indicated by the b-value calculated using the likelihood method ranges from 0.6 – 0.8 and the level of seismic activity as indicated by the a-value ranges between 4.7 – 5.4. The return period for earthquakes ranges from 1,049 – 314.6 years. The results show that region 3 has the largest b-value, namely 0.796. The region that has the largest a-value is region 1, namely 5.405. The shortest earthquake return period is region 1 with 1.049 years and the longest is region 3 with 314.6 years.

Keywords: Sumbawa Islands, b-value, a-value, seismicity, return period.

Introduction

Indonesia is an area prone to earthquake disasters, this is because Indonesia's territory is at the meeting point of three of the world's main tectonic plates, namely the Indo-Australian plate, the Eurasian plate and the Pacific plate as well as one micro plate, namely the Philippine plate. Movements caused by tectonic plates cause Indonesia to frequently be hit by earthquakes of small and large magnitude (Cahyaningsih, L., 2021).

Based on historical records, the island arc area of Sumbawa, Flores and the Alor Islands is known as an area frequently hit by earthquakes. From the 2019 BMKG Catalog of Significant Earthquakes, the southern region of Sumbawa Island was hit by an earthquake with a magnitude of 7 in 1977 which was accompanied by a tsunami wave that claimed 200 lives and hundreds of houses were damaged.

To minimize the danger caused by earthquakes, mitigation measures are needed. One mitigation effort that can be done is to predict the return period of earthquakes that have the potential to cause damage. The likelihood method is a method that can be used to calculate earthquake activity parameters. This method has the advantage, in statistically calculating earthquake activity parameter values, the magnitude interval class can be adjusted to avoid magnitude gaps in certain interval classes (Lumintang, V., Pasau, G., & Tongkukut, 2015). With this method, the level of earthquake activity can be determined from the Guttenberg-Richter equation, seismicity index, earthquake risk level or probability and return period for a certain magnitude in an area quantitatively (Septiani, I & Pujiastuti, D., 2021).

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The return period of an earthquake is the estimated average time between earthquake events of a certain intensity or magnitude in an area. To determine the potential for an area to experience a significant earthquake, it can be detected by knowing the seismotectonic parameters indicated by the a-value and b-value. a-value is a seismic parameter, because a-value can indicate seismic activity in an area and b-value is a tectonic parameter, because b-value reflects the accumulation of stress and the level of brittleness of rocks (Scholz, 1968).

Method

The data used is earthquake data in the Sumbawa Island region for the period 1972-2022 with M ≥ 3 and depth ≤ 30 km. After the data is obtained, the data is grouped based on region. From this data, the b-value and a-value will be calculated. The results of calculating the probability of an earthquake and the return period of an earthquake are analyzed based on magnitude intervals. The calculation begins by calculating the b – value, using Equation 1 (Pertiwi, C.P, 2010):

$$b = \frac{\log e}{\bar{M} - M_0} \qquad (1)$$

Next, the a-value is calculated using Equation 2 (Pertiwi, C.P, 2010):

$$a = \log N + \log(b \ln 10) + M_0 b \qquad (2)$$

After obtaining b-value and a-value, continue calculating the seismicity index using Equation 3, 4, 5, 6 (Pertiwi, C,P, 2010):

$$a' = a - \log(b \ln 10) \qquad (3)$$

$$a'_1 = a' - \log T \qquad (4)$$

$$N_1(M) = 10^{a'_1 - bM} \qquad (5)$$

$$N(M) = N_1(M).10^{-2b} \qquad (6)$$

The probability of an earthquake occurring is found using Equation 7 (Rohadi, 2007):

$$P(M,T) = \left(1 - e^{-N(M)T}\right) \qquad (7)$$

The earthquake return period can be calculated using Equation 8 (Rohadi,2007):

$$\Theta = \frac{1}{N(M)} \qquad (8)$$

Result and Discussion

This research uses secondary data. The map of Sumbawa Island is divided into 4 regions. Region 1 with boundaries of 116,5°-118° East Longitude and 9°-8° South Latitude has 1.167 earthquake events for the M ≥ 3 scale. Region 2 with boundaries of 116,5°-118° East Longitude and 10°-9,001° South Latitude has 379 earthquake events for the M ≥ 3 scale. Region 3 with boundaries of 118,001°-119,3° East Longitude and 9°-8° South Latitude has 358 earthquake events for the M ≥ 3 scale. Region 4 with boundaries of 118,001°-119,3° East Longitude and 10°-9,001° South Latitude has 592 earthquake events for the M ≥ 3 scale.

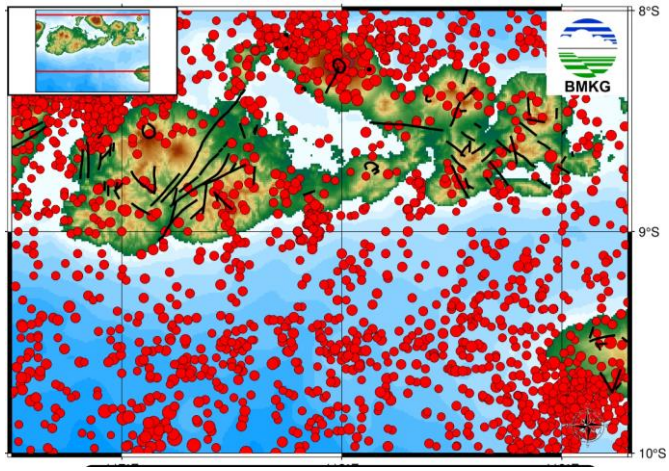

Figure 1. Map of Sumbawa Island

The results of b-value and a-value calculations using the likelihood method can be seen in Table 1. b-value is a tectonic parameter which includes geological environmental conditions, b-value depends on the tectonic characteristics and stress level or material structure of an area (Rahmatulloh, A., 2022). If related to the magnitude of an earthquake in an area, the b-value indicates the level of rock fragility in that area. A low b-value means that the area has a low level of rock fragility and high resistance to pressure. In the Guttenberg-Richter relation, a-value is a spatial parameter to determine seismic characteristics. The size of the a-value depends on the period, area and number of earthquakes that occur in the observation area.

Table 1. Results of b-value and a-value calculations

Region	*b-value*	*a-value*
1	0,689	5,405
2	0,647	4,758
3	0,796	5,284
4	0,709	5,182

The seismicity index is the cumulative frequency of earthquakes per year based on magnitude. The results of the seismicity index calculation can be seen in tables 2, 3, 4, and 5. The probability of an earthquake occurring is the possibility of a damaging earthquake occurring in an area within a certain time period. The value of earthquake probability can be used as a mitigation effort in development planning that is more resistant to earthquake shocks. The earthquake return period is used to determine the recurrence of

earthquakes with a certain magnitude in a region. If a region has a low return period, that region is prone to earthquakes.

Table 2. Region 1 calculations

Region 1					
Mag	*b*	*a*	(N(M))	P(M,T)	(θ)
3,1			0,952	99,99	1,049
3,3			0,693	99,90	1,4
3,4			0,591	99,7	1,7
3,5			0,504	99,3	1,9
3,6			0,43	98,6	2,3
3,7			0,367	97,4	2,7
3,8			0,313	95,6	3,2
3,9			0,267	93,1	3,7
4			0,228	89,7	4,3
4,1			0,194	85,7	5,1
4,2			0,166	80,9	6
4,3			0,141	75,7	7,1
4,4			0,12	70,1	8,2
4,5	0,689	5,405	0,103	64,3	9,7
4,6			0,087	58,5	11,3
4,7			0,075	52,7	13,3
4,8			0,064	47,2	15,6
4,9			0,054	42,1	18,3
5,1			0,039	32,8	25,1
5,2			0,033	28,7	29,4
5,3			0,028	25,1	34,5
5,4			0,024	21,8	40,5
5,6			0,017	16,4	55,6
5,7			0,015	14,2	65,2
5,8			0,013	12,2	76,4
6,2			0,006	6,6	144,3
6,3			0,005	5,7	169,1

Table 3. Region 2 calculations

Region 2					
Mag	*b*	*a*	(N(M))	P(M,T)	(θ)
3,1			0,376	97,6	2,6
3,2			0,324	96,1	3,1
3,3			0,279	93,8	3,5
3,4			0,24	91	4,1
3,5			0,207	87,4	4,8
3,6			0,178	83,2	5,5
3,7			0,153	78,5	6,4
3,8			0,132	73,4	7,5
3,9	0,647	4,758	0,114	68,1	8,7
4			0,098	62,6	10,1
4,1			0,084	57,1	11,7
4,2			0,073	51,8	13,6
4,3			0,063	46,7	15,8
4,4			0,054	41,8	18,4
4,5			0,046	37,3	21,4
4,6			0,04	33,1	24,8
4,7			0,034	29,2	28,8
4,8			0,029	25,8	33,4
4,9			0,025	22,6	38,8
5,2			0,016	15,1	60,7
5,3			0,014	13,4	70,5
5,4			0,012	11,7	81,9
5,6			0,009	8,6	110,3
5,7			0,007	7,5	128,1
5,9			0,005	5,6	172,6
6,1			0,004	4,2	242,5

Table 4. Region 3 calculations

Region 3					
Mag	*b*	*a*	(N(M))	P(M,T)	(θ)
3,1			0,179	83,3	5,5
3,2			0,149	77,5	6,7
3,3			0,124	71,1	8
3,4			0,103	64,4	9,6
3,5			0,086	57,7	11,6
3,6			0,071	51,1	13,9
3,7			0,059	44,9	16,7
3,8			0,049	39,1	20,1
3,9			0,041	33,8	24,1
4			0,034	29,1	29
4,1	0,796	5,284	0,028	24,9	34,8
4,2			0,023	21,2	41,8
4,3			0,019	18	50,3
4,4			0,016	15,2	60,4
4,5			0,014	12,8	72,6
4,6			0,011	10,8	87,2
4,7			0.009	9,1	104,7
4,8			0,007	7,6	125,8
4,9			0,006	6,4	151,1
5			0,005	5,3	181
5,1			0,004	4,4	218
5,3			0,003	3,7	314,6

Table 5. Region 4 calculations

Region 4					
Mag	*b*	*a*	(N(M))	P(M,T)	(θ)
3,1			0,443	98,8	2,2
3,2			0,376	97,6	2,6
3,3			0,319	95,9	3,1
3,4			0,271	93,3	3,6
3,5			0,23	90	4,3
3,6			0,195	85,9	5,1
3,7			0,166	81	6
3,8			0,141	75,6	7
3,9	0,709	5,182	0,12	69,8	8,3
4			0,101	63,9	9,8
4,1			0,086	57,9	11,5
4,2			0,073	52	13,5
4,3			0,062	46,4	16
4,4			0,053	41,1	18,8
4,5			0,045	36,2	22,1
4,6			0,038	31,8	26,1
4,7			0,032	27,7	30,7

4,8	0,027	24,1	36,2
4,9	0,023	20,9	42,6
5,1	0,016	15,5	59
5,4	0,01	9,8	96,4
5,5	0,008	8,4	113,5

Conclusion

Based on the results and discussion of the research that has been carried out, it can be concluded that: 1). The b-value calculation results for the 4 regions range between 0.6-0.7. Region 1 is 0.689, region 2 is 0.647, region 3 is 0.796, and region 4 is 0.709. The a-value calculation for the 4 regions ranges from 4.7-5.4. Region 1 was 5,405, region 2 was 4,758, region 3 was 5,284, and region 4 was 5,182. The region that has the largest b-value is region 3 and the region that has the largest a-value is region 1; 2). Calculation results of earthquake return periods for 4 regions range between 1.049-314.6 years. Region 1 with an earthquake return period of 1.049-169.1 years, region 2 with an earthquake return period of 2.6-242.5 years, region 3 with an earthquake return period of 5.5-314.6 years, and region 4 with an earthquake return period 2.2-113.5 years. The region that has the shortest return period is region 1, while the region that has the longest return period is region 3.

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