Analysis of the Social Vulnerability Index for the Mount Agung Eruption Disaster, Karangasem Regency, Bali

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Abstract

Indonesia is an archipelagic country located between the continents of Asia and Australia as well as the Indian and Pacific Oceans. Geographically, Indonesia is located between 6°N-11°S and 95°-141°E. The location of the mountains in Indonesia varies greatly because this country has many islands with diverse topography. The social vulnerability index for volcanic eruptions includes the parameters of population density, vulnerable age ratio, sex ratio, disabled population ratio, and poor population ratio. This research aims to determine the value of the social vulnerability index in each area within the eruption radius of Mount Agung if an eruption occurs. The methods used in data collection are secondary and primary data collection methods. The method for processing data is quantitative descriptive statistical data analysis called factor analysis and scoring analysis based on PERKA BNPB No. 2 of 2012 with the results of a risk level scoring for each parameter of the social vulnerability index. The results obtained from this research are the risk level of the social vulnerability index in the Karangasem district. The highest social vulnerability index is in the sub-districts of Banyakdem and Karangasem with a score of 26 and the lowest sub-district is Kubu sub-district with a score of 15. The Sedimen sub-district with a score of 25, the Manggis and Selat sub-districts with a score of 24, the Abang sub-district 20, and the Rendang sub-district 18.

Keywords: *Mount Agung, Social Vulnerability, PERKA BNPB No 2 Tahun 2012*

1. Pendahuluan

Indonesia is an archipelagic country located between the continents of Asia and Australia as well as the Indian and Pacific Oceans. Geographically, Indonesia is located between 6°N-11°S and 95°-141°E. The location of the mountains in Indonesia varies greatly because this country has many islands with diverse topography. Some famous mountains in Indonesia include: (1) Mount Kerinci: Located in Jambi Province, Sumatra. Mount Kerinci is the highest mountain in Indonesia with a height of around 3,805 meters above sea level. (2) Mount Semeru: Located in East Java. Mount Semeru is the highest mountain on the island of Java and has a height of around 3,676 meters above sea level. (3) Mount Rinjani: Located on Lombok Island, West Nusa Tenggara. Mount Rinjani has a height of around 3,726 meters above sea level. (4) Mount Bromo: Located in East Java. Even though it is not the highest mountain, Mount Bromo is very famous for its charming views. Its height reaches around 2,329 meters above sea level. (5) Mount Agung: Located on the island of Bali. Mount Agung is the highest mountain in Bali with a height of around 3,142 meters above sea level. (6) Mount Tambora: Located on Sumbawa Island, West Nusa Tenggara. Mount Tambora is known for its violent eruption in 1815 which created a large crater lake.[1]

The level of vulnerability to a volcano is usually evaluated by considering a number of factors that can influence the impact of an eruption on the environment and humans. Several factors that are generally taken into account in determining the level of vulnerability of a volcano involve the

following aspects: (1) Volcanic Activity: History of volcanic eruptions and tendencies in eruptive behavior. The level of seismic activity and magma activity inside a volcano. (2) Population Density: The number of people living around the volcano. Settlement distribution and population density. (3) Infrastructure and Economy: Location and type of infrastructure in the area, such as houses, roads and public facilities. Economic impacts that may occur due to the eruption. (4) Accessibility: Ease of access to the area, including evacuation routes. Availability of good and accessible evacuation routes. (5) Disaster Preparedness and Planning: Availability of disaster mitigation and early warning plans. Warning and evacuation system capacity. (6) Environmental: The impact of eruptions on the environment, including agricultural land, water sources and natural ecosystems. (7) Social and Welfare: Community capacity to adapt and respond to eruptions. Social factors and community welfare. (8) Education and Community Awareness.The level of public understanding about the dangers of volcanic eruptions. Effectiveness of education and outreach campaigns. It is important to note that evaluating the level of vulnerability is complex and involves cross-sector research. Governments and related agencies, such as geological agencies and disaster agencies, are usually involved in determining the level of volcanic vulnerability in a region. This evaluation is needed to develop disaster mitigation strategies and increase community preparedness against the potential threat of volcanic eruptions.[2]

Vulnerability is a condition of a community or society that leads to or causes an inability to face the threat of disaster. Vulnerability maps can be divided into social, economic, physical, and ecological/environmental vulnerabilities. Susceptibility can be defined as Exposure times Sensitivity. Exposed "assets" include human life (social vulnerability), economic areas, physical structures, and ecological/environmental areas. Each "asset" has its sensitivity, which varies per disaster (and disaster intensity). The indicators used in vulnerability analysis are primarily exposure information. In two cases information is included on the composition of exposure (such as population density, sex ratio, poverty ratio, disabled person ratio, and age group ratio). Sensitivity is only covered indirectly through the distribution of weighting factors.[2]

Scoring or value weighting is carried out only on the social vulnerability index where this index has several assessment parameters, namely population density, gender, vulnerable age groups, poor people, and disabled people.[2],[3]

Table 1. Weighting of Social Vulnerability Values

Parameter	Weight (%)	Class		
		Light	Currently	Heavy
Population density	60	< 5 People /Ha	5 – 10 People /Ha	>10 People/Ha
Vulnerable Groups				
Sex Ratio (10%)	40	>40%	20-40%	<20%
Vulnerable Age Group Ratio (10%		<20%	20-40%	>40%
Poor Population Ratio (10%)				
Disabled Population Ratio (10%)				

Source : Perka BNPB No 2 Tahun 2012

Social Vulnerability Index base on Perka BNPB no 2 tahun 2012 is :[2], [4]

$$Social\ Vulnerability = (0,6\ x\ Population\ Density\ Score) + (0,1\ \ Sex\ Ratio) + (0,1\ x\ Vulnerable\ Age\ Group\ Ratio) + (0,1\ x\ Poor \quad (1)$$

While carrying out this research, the author also needs secondary data which will later be processed in the discussion stage.[3]

Table 2. Research Data Requirements

No	Data Type	Research Variable	Agency or Source	Data Persentation
1	Secondary Data	Social Vulnerability Processing demographic data in areas or zones affected by Mount Agung with indicators 1. Population density 2. Vulnerable Groups	Literature Review : BNPB, Affected Districts, and BPS Kab. Karamgasem	Mapping, Tables, and Descriptives

Source : Author 2022

Weighting and scoring of social vulnerability parameters include population density, gender, vulnerable age groups, poor people, and disabled people. The scoring value used is 10 for the low category, 20 for the medium category, and 30 for the high category. The total social vulnerability of an area can be determined by adding up the weights of population density and vulnerable groups according to the social vulnerability formula. For interval parameters, population density is calculated using the following formula. (1) This population density will later become a reference for determining scoring on population density parameters.[5]

$$Population\ Density = \frac{Highest\ Population\ Density - Smallest\ Population\ Density}{Number\ of\ Intervals} \quad (2)$$

(2) Gender is the second parameter that must also be taken into account. It is assumed that if the sex ratio of men is more than women, it can be interpreted as being at a low level. In this study, a male-to-male ratio above 100 can be interpreted as having a low-risk level, then a ratio equal to 100 is a medium-risk level, and a ratio below 100 is a high-risk level.[5]

$$Sex\ Ratio = \frac{Number\ of\ Male\ Population}{Number\ of\ Female\ Population}\ x\ 100 \quad (3)$$

(3) The vulnerable age group influences social vulnerability. The vulnerable age group is divided into the age group 0 – 14 years, 15 – 64 years, and the age group over 65 years. Before determining the age group ratio, the dependency ratio must first be determined.[5]

$$Vulnerable\ Age\ Group\ Ratio = \frac{P(>65Th)+P(<5Th)}{P(15-64)Th}\ x\ 100 \quad (4)$$

This dependency ratio is used to determine the interval class of the vulnerable age group ratio. Vulnerable age group intervals as a basis for determining the risk level of vulnerable age groups.

$$Vulnerability\ Interval = \frac{Highest\ Dependency\ Ratio - Low\ Dependency\ Ratio}{Interval\ Class} \quad (5)$$

(4)The ratio of disabled people in an area is an indicator that is taken into account in determining social vulnerability. The more disabled people, the higher the possibility of loss of life during a volcanic eruption. Determining the risk level first determines the interval of the number of disabled people in one area.

$$Disabled\ Population\ Ratio = \frac{Highest\ number\ of\ disabled\ people - Lowest\ number\ of\ disabled\ people}{Number\ of\ Intervals} \quad (6)$$

(5) The number of poor people in an area will also influence social vulnerability during a volcanic eruption. When a volcanic disaster occurs, the poorest groups of people who are most vulnerable become victims during and after a volcanic disaster.[5]

$$Poor\ Population\ Ratio = \frac{Highest\ Number\ of\ Poor\ Population - Lowest\ Number\ of\ Poor\ Population}{Number\ of\ Interval} \quad (7)$$

Table 3. Classification of Volcanic Eruption Disaster Weighting Parameters

Parameter	Size	Scoring	Weight	Total Weight
Population Density	<500 Jiwa/Km^2	10	60 %	100 %
	500 – 1000 Jiwa/Km^2	20		
	>1000 Jiwa/Km^2	30		
Sex Ratio	<20 %	10	40 %	
	20 – 40 %	20		
	>40 %	30		
Vulnerable Age Group Ratio	<20 %	10		
	20 – 40 %	20		
	>40 %	30		
Poor Population Ratio	<20 %	10		

	20 – 40 %	20
	>40 %	30
Disabled Population Ratio	<20 %	10
	20 – 40 %	20
	>40 %	30

Source : Perka BNPB No 2 Tahun 2012

2. Methodology

The method in this research was carried out in several stages. (1) The first is to identify and analyze the problems in the case study area that will be discussed, in this case, the area around Mount Agung. (2) the second step is literature study and literature study, in this case collecting theoretical information related to volcanic disasters and how to assess volcanic vulnerability. (3) the third step is collecting secondary data and primary data, which is obtained from agencies or the results of interviews and questionnaires. (4) the fourth step is the analysis and determination of the vulnerability index scoring of all sub-districts in the Karangasem district. This vulnerability index consists of the criteria for population density, gender, poverty, disabled people, and age group. (5) conclude from the results of existing data processing. The above is the method that will be used in this research.

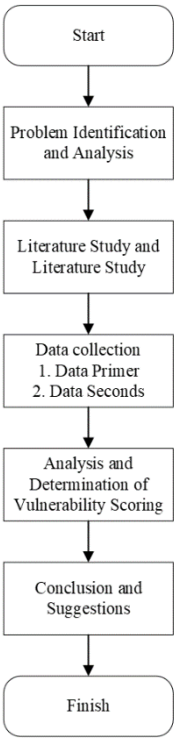


Figure 1. Stages of the Research Process

3. Results and Discussion

(1) Data collection is the first activity carried out. During the research process, secondary data was obtained from each sub-district in the Karangasem district based on the explanation in the introductory chapter in Table 2. To determine the level of risk in the population density parameter, first determine the interval when it is said to be high, medium, and low risk.

Table 4. Population Density Data for Districts, Karangasem Regency, Bali

No	Districts	Population Density / Km^2
1	Abang	466
2	Bebandem	566
3	Karangasem	921
4	Kubu	251

5	Manggis	651
6	Selat	491
7	Sidemen	934
8	Rendang	358

Source : Authors 2022

Based on the data obtained in table 3, intervals can be determined for population density parameters.

$$Population\ Density = \frac{Highest\ Pupulation\ Density - Smallest\ Population\ Density}{Number\ of\ Intervals}$$

$$Population\ Density = \frac{934-251}{3}$$

$$Population\ Density = 227,66 \approx 228$$

From the results of calculating population density intervals, an interval for population density is obtained, where low vulnerability is <228 people/km2, medium vulnerability 228 – 456 People/Km2, and high vulnerability >457 People/Km2. From the results of the vulnerability analysis of population density, it is known that the Kubu sub-district is in the low vulnerability level category with a score of 10, Abang and Rendang sub-districts are in the medium vulnerability level with a score of 20, and the Banyakdem, Karangasem, Manggis, Selat, and Sidemen sub-districts are in the high level. with a score of 30.

(2) The sex ratio also calculates the risk level. Before carrying out this calculation, data is needed in the form of the number of men and women. This interval is divided into 3, low vulnerability with a value above 100, medium vulnerability if the value is equal to 100, and high vulnerability with a value below 100.

Table 5. Sex Ratio Data

No	Districs	Gender		Total Population
		Male	Female	
1	Abang	31330	31030	62360
2	Bebandem	22870	23200	46070
3	Karangasem	43380	43400	86780
4	Kubu	30050	28670	58720
5	Manggis	22480	22950	45430
6	Selat	19450	19930	39380
7	Sidemen	16160	16660	32820
8	Rendang	19780	19470	39250

Sumber : Penulis 2022

Table 6. Sex Ratio Vulnerability Level Calculation Results

No	Districts	Gender		Sex Ratio Susceptibility	Sex Ratio Susceptibility Level
		Male	Female		
1	Abang	31330	31030	100,96	20
2	Bebandem	22870	23200	98,57	30
3	Karangasem	43380	43400	99,95	30
4	Kubu	30050	28670	104,81	10
5	Manggis	22480	22950	97,95	30
6	Selat	19450	19930	97,59	30
7	Sidemen	16160	16660	96,99	30
8	Rendang	19780	19470	101,59	10

Source : Authors 2022

(3) Vulnerable age groups have a different calculation analysis, first, the dependency ratio must be carried out and then the vulnerability interval must be determined.

Table 7. Vulnerable Age Group Data

No	Districts	Age Group		
		0-14	15-64	>65
1	Abang	16350	39910	6090
2	Bebandem	11280	30200	4590
3	Karangasem	22730	57450	6600
4	Kubu	18750	34700	5270
5	Manggis	11380	29530	4520

6	Selat	9360	25960	4060
7	Sidemen	8170	19330	3030
8	Rendang	9380	26330	3540

Source : Authors 2022

Table 8. Vulnerability Ratio Calculation Results for Vulnerable Age Groups

No	Districts	Age Group			Dependency Ratio
		0-14	15-64	>65	
1	Abang	16350	39910	6090	56,22
2	Bebandem	11280	30200	4590	52,54
3	Karangasem	22730	57450	6600	51,05
4	Kubu	18750	34700	5270	69,22
5	Manggis	11380	29530	4520	53,84
6	Selat	9360	25960	4060	51,69
7	Sidemen	8170	19330	3030	57,94
8	Rendang	9380	26330	3540	49,06

Source: Author's Data Analysis 2022

After obtaining the dependency ratio value, the next step is to determine the risk interval for gender susceptibility.

$$Vulnerability\ Interval = \frac{High\ dependency\ ratio - low\ dependency\ ratio}{Number\ of\ Interval}$$

$$Vulnerability\ Interval = \frac{69{,}22 - 49{,}06}{3}$$

$$Vulnerability\ Interval = 6,72$$

Based on the results of calculating the vulnerability interval, it can be grouped as follows, low vulnerability is 49.06 – 55.78 with a score of 10, medium vulnerability is 55.79 – 62.72 with a score of 20, and high vulnerability is 62.73 – 69.45 with a score of 30. The vulnerability index for the low vulnerable age group is in the sub-districts of Rendang, Selat, Manggis, Karangasem, and Banyakdem with a score of 10. The medium vulnerability index is in the Abang and Sediment sub-districts with a score of 20. The high vulnerability index is in the Kubu sub-district with a score of 30.

(4) The disabled population is also a threat in handling the eruption of Mount Agung. The vulnerability index for the disabled population is first calculated by the existing vulnerability interval.

Table 9. Disabled population Data

No	Districts	Number of disabled people
1	Abang	0
2	Bebandem	2
3	Karangasem	3
4	Kubu	24
5	Manggis	2
6	Selat	0
7	Sidemen	0
8	Rendang	58

Source : Authors 2022

$$Ratio\ of\ disabled\ people = \frac{The\ highest\ number\ of\ disabled\ people - lowest\ number\ of\ disabled\ people}{Number\ Of\ Interval}$$

$$Ratio\ of\ disabled\ people = \frac{58-0}{3}$$

$$Ratio\ of\ disabled\ people = 19,33 \approx 19$$

From the interval calculation results, it was found that low vulnerability was at a value of 0 – 19, medium vulnerability was 20 – 39, and high vulnerability was 40 – 59. The low vulnerability index was in the districts of Abang, Banyakdem, Karangasem, Manggis, Selat, and Sediment with a score of 10, the vulnerability index medium in the Kubu sub-district with a score of 20, and a high vulnerability index in Rendang sub-district with a score of 30.

(5) The last vulnerability parameter is the poor population parameter. Poor people are considered to have a high vulnerability to volcanic eruptions. If there are more poor people, the potential for loss of life will also be higher, namely when a disaster occurs and after a disaster occurs. Before determining the level of risk of poor people, first determine the interval of poor people.

Table 10. Poor Population Data

No	Districts	Number Of Poor Pupulation
1	Abang	5567
2	Bebandem	4350
3	Karangasem	5549
4	Kubu	4760
5	Manggis	1659
6	Selat	2235
7	Sidemen	1700
8	Rendang	1300

Source : Authors 2022

$$Ratio\ Poor\ Population = \frac{Highest\ Number\ Poor\ Population - Lowest\ Number\ Poor\ Population}{Number\ of\ Interval}$$

$$Ratio\ Poor\ Population = \frac{5567-1300}{3} = 1422,33 \approx 1422$$

From the calculation results, the ratio interval for the poor population is obtained as follows. The ratio of poor people with a low level of vulnerability is 1300 – 2722, a medium level of vulnerability is 2723 – 4145 and a high level of vulnerability is 4146 – 5568. The vulnerability index for poor people in Karangasem district for the low level is Rendang, Sidemen, Selat, and Mangosteen subdistricts for the medium level. and the high level is in the Abang,Bebandem, Karangasem and Kubu sub-districts..

Table 11. Karangasem Regency Social Vulnerability Index

Districts		Parameter	Weight (%)	Index Class			Score
				Low	Medium	Hight	
Abang	1	Population Density	60 %		20		12
	2	Sex Ratio	40%		20		2
	3	Vulnerable Age Group Ratio			20		2
	4	Poor Population Ratio		10			1
	5	Disabled Population Ratio				30	3
	Social Vulnerability Index Total						**20**
Bebandem	1	Population Density	60 %			30	18
	2	Sex Ratio	40%			30	3
	3	Vulnerable Age Group Ratio		10			1
	4	Poor Population Ratio		10			1
	5	Disabled Population Ratio				30	3
	Social Vulnerability Index Total						**26**
Karangasem	1	Population Density	60 %			30	18
	2	Sex Ratio	40%			30	3
	3	Vulnerable Age Group Ratio		10			1
	4	Poor Population Ratio		10			1
	5	Disabled Population Ratio				30	3
	Social Vulnerability Index Total						**26**
Kubu	1	Population Density	60 %	10			6
	2	Sex Ratio	40%	10			1
	3	Vulnerable Age Group Ratio				30	3
	4	Poor Population Ratio			20		2
	5	Disabled Population Ratio				30	3
	Social Vulnerability Index Total						**15**
Manggis	1	Population Density	60 %			30	18
	2	Sex Ratio	40%			30	3
	3	Vulnerable Age Group Ratio		10			1
	4	Poor Population Ratio		10			1
	5	Disabled Population Ratio		10			1
	Social Vulnerability Index Total						**24**
Selat	1	Population Density	60 %			30	18
	2	Sex Ratio	40%			30	3
	3	Vulnerable Age Group Ratio		10			1
	4	Poor Population Ratio		10			1

Districts		Parameter	Weight (%)	Index Class			Score
				Low	Medium	Hight	
	5	Disabled Population Ratio		10			1
	Social Vulnerability Index Total						**24**
Sedimen	1	Population Density	60 %			30	18
	2	Sex Ratio	40%			30	3
	3	Vulnerable Age Group Ratio			20		2
	4	Poor Population Ratio		10			1
	5	Disabled Population Ratio		10			1
	Social Vulnerability Index Total						**25**
Rendang	1	Population Density	60 %		20		12
	2	Sex Ratio	40%	10			1
	3	Vulnerable Age Group Ratio		10			1
	4	Poor Population Ratio				30	3
	5	Disabled Population Ratio		10			1
	Social Vulnerability Index Total						**18**

Source: Author's Data Analysis 2022

4. Conclusion

The results of this research are the results of mapping the level of risk in each sub-district in Karangasem district in facing or experiencing a disaster if Mount Agung erupts. The risk level is only calculated on social vulnerability. The highest social vulnerability index is in the Banyakdem and Karangasem sub-districts with a score of 26, then the lowest social vulnerability index is in the Kubu sub-district with a score of 15.

Table 12. Karangasem Regency Social Vulnerability Index Level

No	Districts	Score
1	Bebandem	26
2	Karangasem	26
3	Sidemen	25
4	Manggis	24
5	Selat	24
6	Abang	20
7	Rendang	18
8	Kubu	15

Source : Authors 2022

From the results of determining the level of this social vulnerability index, it can be used by BPBD or parties related to the local evacuation or natural disaster response team as a reference in handling and evacuating residents during the eruption of Mount Agung. From the results above, the districts of Banyakem and Karangasem could become priority districts in the process of evacuating residents during the eruption of Mount Agung because they have the highest vulnerability.

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