Social vulnerability of Pandeglang Regency, Banten

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Abstract. The potential for natural disasters in Pandeglang Regency is enormous considering that various kinds of disasters can occur in Pandeglang Regency. There needs to be comprehensive efforts to reduce the impact of the risk of natural disasters, one of them is by knowing the level of social vulnerability of the community in Pandeglang. Social vulnerability calculates the level of social vulnerability of the community to scenarios of natural disasters. This study aims to determine the level of social vulnerability and its distribution. Concept method of Social Vulnerability Index (SOVI) is used to measure regional vulnerability based on social indicators to disasters using the aspects of exposure, sensitivity and adaptive capacity. The variables used are population density, proportion of informal sector workers, proportion of vulnerable age population, proportion of non-permanent houses, proportion of prosperous households, proportion of high school graduates and number of social institutions. The level of vulnerability that dominates is a low vulnerability area by number 25 sub-districts or 71.42 % while there are 9 sub-districts or 25.71 % for high vulnerability areas and only 1 sub-district or 2.85 % of high vulnerability areas, namely Cimanuk District, which is in the northern part of Pandeglang Regency. Based on the value of vulnerability in several areas that still show a fairly large level of medium-high vulnerability. So, this data can be used as a recommendation as early mitigation measures to reduce the level of social vulnerability in order to reduce the impact that will later be caused.

Keywords: Adaptive capacity, exposure, natural disaster, population density, social vulnerability index

1. Introduction
Indonesia is one part of the Asia-Pacific ring of fire which is then prone to disasters. One cause of many disasters is because of the location of Indonesia which lies at the junction of three plates, namely the Indo-Australian Plate in the South, the Euro-Asia Plate in the North and the Pacific Plate in the East [1]. Considering that Indonesia’s location is in an earthquake-prone location, Indonesia needs a reliable disaster management capability [2]. Apart from prevention efforts, disaster management itself is also needed [3]. Therefore, a deep and comprehensive understanding of various aspects of disasters is also needed [4]. One aspect that needs to be understood in disaster management efforts is the social aspect. According to Law Number 24 of 2007, disaster is an event or series of events that threatens and disrupts the life and livelihood of the community which is caused, either by natural factors and / or non-natural factors and human factors, resulting in human casualties, environmental damage, property loss and psychological impacts. Disasters occur because of threats, impacts and vulnerabilities [5]. Disasters can threaten all areas in Indonesia, both in land, mountainous and coastal areas including
Pandeglang district. Moreover, Banten Province is close to the Sunda Megathrust, a large active fault that can become the epicenter of shallow earthquakes, making it prone to earthquakes and tsunamis [6].

Geologically, this district has a very complex tectonic arrangement, which is located between various oceanic plates and continental plates that are actively moving all the time [7]. In this area, there is a meeting point of the three world plates, namely the Indo-Australian Plate, the Eurasian Plate and the Pacific Plate [8]. With the presence of the meeting of the three plates, this area is prone to collisions between the Eurasian continental plate and the Indo-Australian oceanic plate and the Pacific oceanic plate [7]. Along the subduction zone on the continental plate, a group of volcanic islands or volcanic belts (magmatic belt) is formed along Sumatra, southern Java to Nusa Tenggara to Banda, calls it the Sunda - Banda magmatic arc or the Sunda volcanic arc – Banda [9]. These mountain ranges form a ring of volcanic mountains that surround the territory of Indonesia so it is called the “Ring of Fire” [10]. This geological condition causes Indonesia, especially along the Sunda-Banda Arc where Pandeglang Regency is part of it, to be very vulnerable to natural disasters with geological aspects such as earthquakes, tsunamis, volcanic eruptions, landslides and others [11].

Almost every year Pandeglang Regency is always hit by disasters ranging from landslides, floods, whirlwinds to the danger of tsunamis and earthquakes. Pandeglang Regency is included in 20 disaster-prone areas at the national level [2]. In fact, Pandeglang Regency in 2018–2019 experienced 13 types of earthquake disasters with high frequency and cost a lot of losses [12]. One incident is thought to have resulted in a tsunami, namely an avalanche from part of Mount Anak Krakatau’s body into the sea after the eruption of 22 December 2018 [13]. Based on this incident, it impacts Pandeglang Regency with 431 fatalities, 1,527 houses damaged, 70 moderate damage houses and slightly damaged 181 houses.

The population of Pandeglang Regency based on projections in 2019 is 1,209,011 people with a population composition of 617,012 men and 591,999 women [14]. Based on these data, the gender ratio in 2019 is 3643.75 [14]. The sub-district with a sparse population is Koroncong District, while the most densely populated area is Labuan District [14].

Based on the general description of the existing area, Pandeglang Regency has a large potential disaster hazard, both from a geographical, physiographic and demographic point of view [10]. Various efforts have been made to minimize the impact that occurs in the event of a disaster in Pandeglang Regency, one of which is by knowing the vulnerability of the area. Vulnerability is the level or degree to which a system is vulnerable and unable to overcome the adverse effects of a hazard [3]. Vulnerability to disasters can be assessed in various aspects such as physical vulnerability, social vulnerability, economic vulnerability and environmental vulnerability [1]. The social conditions of the community also affect the level of vulnerability to hazards. Moreover, the population growth rate of Banten Province is greater than the national growth rate of 2.1% from 2012 to 2019, while the national growth rate is 1.67% [14]. Population growth is the change in population in a certain area at a certain time compared to the previous time.

Social vulnerability describes the social vulnerability of an area due to the influence of hazards, threats and disasters that have the potential to damage, disturb and harm [15]. The lack of disaster mitigation efforts and also the lack of means for citizen participation are in stark contrast to the increasing number of people in Pandeglang district. Based on the Regulation of the Head of the National Disaster Management Agency (BNPB) No. 2 of 2012 concerning General Guidelines for Disaster Risk Assessment, the level of social vulnerability can be assessed from population density, proportion of informal sector workers, proportion of vulnerable age population, proportion of non-permanent housing, proportion of wealthy households, proportion of high school graduates and number of social institutions. In this case, the community will become the main object when a disaster occurs. Basically, the community should have the ability to identify existing social vulnerabilities, so that they can become the main actors in disaster risk reduction efforts, so that losses can be minimized [16].

This study aims to determine the level of social vulnerability and its distribution using the Social Vulnerability Index (SOVI) concept method. This method is used to measure the vulnerability of an area based on social indicators to disasters using the aspects of exposure, sensitivity and adaptive capacity and several measurement variables that have been previously described. Given that Pandeglang regency
has a level of resilience that is categorized as good with a high risk of disaster [17]. Considering the high seismic activity in the area around Pandeglang because of the slabs in the Sunda Trench and Mount Krakatau areas, it is therefore very necessary to conduct research on social vulnerability in order to know the level of exposure and resilience of Pandeglang Regency which later the data obtained can be used as a reference for evaluation in order to minimize the losses that will be caused later.

2. Research method
Social vulnerability in the study was assessed by considering social aspects in Pandeglang Regency which are guided by the concept of the Social Vulnerability Index (SOVI) to measure regional vulnerability based on social indicators to disasters in Pandeglang Regency. Based on the SOVI concept from Cutter et al. [18] several variables in regional vulnerability were taken based on social indicators. First, from the aspect of exposure, there is a variable between the population and workers in the informal sector. Second, from the sensitivity aspect, which has a variable between the population of vulnerable ages and the proportion of houses that are not permanent. Third, from the aspect of adaptive capacity, there is a variable between the proportion of prosperous households, the population who graduated from high school (SMA) and aspects of social institutions.

In processing vulnerability data, this study uses parameter calculations and standardizes the data so that they have the same size. The criterion score in the standardization process has the aim of converting various parameters into comparable units [19]. To standardize criteria, there are several methods, one of which uses linear scale transformation. The parameters used in the variables are secondary data, most of which cannot be measured, so it is necessary to calculate the parameters of each variable for each region. The purpose of calculating this parameter is to calculate the proportion of each variable for each region. The calculation for each parameter can be seen in table 1.

| Table 1. Calculation of research variable parameters. |
|-----------------------------------------------------|
| Parameter                                           | Parameter calculation                                      |
| Population density                                  | $\frac{\sum \text{Population}}{\text{District Area}}$    |
| Proportion of informal workers                      | $\frac{\sum \text{residents who work in the informal sector}}{\sum \text{working population}}$ |
| Proportion of vulnerable population                 | $\frac{\sum \text{population aged 0 - 4 years} + \sum \text{population aged > 60 years}}{\sum \text{district residents}}$ |
| Proportion of non permanent house                   | $\frac{\sum \text{non permanen houses}}{\sum \text{total of houses}}$ |
| Proportion of prosperous households                 | $\frac{\sum \text{prosperous household}}{\sum \text{household}}$ |
| Proportion of high school graduated                 | $\frac{\sum \text{residents of high school graduates}}{\sum \text{resident graduated from elementary school} + \sum \text{junior high school and above}}$ |
| Sosial capital aspect                               | $\sum \text{Community Organization}$                      |
After calculating these parameters, the vulnerability parameter data is standardized first with the aim to equalize the size of the value for each parameter so that it has the same value. The data standardization process produces a form of similarity, namely the minimum value of the range is equal to one (1) and the maximum value of the range is equal to two (2) to avoid data bias when using zero (0) values. The form of the data standardization equation is as follows:

$$X' = a + \frac{(Xi - Xmin)(b - a)}{Xmax - Xmin}$$  \hspace{1cm} (1)

where

- $X'$: Standardized data values
- $Xi$: The value of the i-th data
- $Xmax$: The maximum value of data
- $Xmin$: Minimum value of data
- $a$: Minimum range value
- $b$: The maximum range value

This study contains variables that have criteria according to the level of vulnerability of the region. The calculation process is carried out to determine the range of values in the vulnerability of the region as we shown in table 2.

| Variable                              | Assumption                                                                 | Vulnerability rate   |
|---------------------------------------|-----------------------------------------------------------------------------|----------------------|
| Population density                    | The higher the level of population density, the higher the level of exposure | Low: < 2.150 Life/km² Moderate: 2.150–3650 Life/km² High: > 3,650 Life/km² |
| Proportion of informal sector workers | The higher proportion of the population working in the informal sector will have a higher level of exposure | Low: < 0.13 0.13–0.81 Moderate: > 0.81 |
| Proportion of vulnerable population   | The higher the proportion of the elderly-toddler population, the higher the level of sensitivity | Low: < 0.21 0.21–0.23 Moderate: > 0.23 |
| Proportion of non-permanent houses    | The more types of non-permanent houses, the higher the sensitivity           | Low: < 0.27 0.27–0.84 Moderate: > 0.84 |
| Proportion of prosperous households   | The more the number of prosperous households, the level of adaptive capacity will be higher so that vulnerability will be lower | Low: < 0.02 0.02–0.03 Moderate: > 0.03 |
| Proportion of population with a high level of education | The more population with a high level of education the higher the adaptive capacity, the lower the vulnerability | Low: < 0.25 0.25–0.81 Moderate: > 0.81 |
| Senior high school graduated          | Sub-districts that have community organizations will be better in dealing with disasters so that high adaptive capacity and vulnerability will be lower | Low: < 133 133–190 Moderate: > 190 |
Table 3. Interval class classification for each indicator.

| Classes/indicator | Exposure | Sensitivity | Adaptive capacity | Vulnerability |
|-------------------|----------|-------------|-------------------|---------------|
| Low               | < 0.30   | < 0.30      | < 0.30            | < 0.30        |
| Moderate          | 0.30–0.60| 0.30–0.60   | 0.30–0.60         | 0.30–0.60     |
| High              | > 0.60   | > 0.60      | > 0.60            | > 0.60        |

The indicators of vulnerability that have been added to each variable and standardized in this study are categorized into five classes using the equal interval method, which each class has the same interval as in table 3.

Vulnerability is a function of the character, magnitude, and rate of climate variation to the exposure system or level of exposure, level of sensitivity, and adaptive capacity. It can also be formulated mathematically with vulnerability (V) a function of exposure (E), sensitivity (S) and adaptive capacity (A) [20]. In determining the level of vulnerability of a particular system, all indicators must be integrated into an index called the vulnerability index. To obtain the level of regional vulnerability based on social indicators, the formula is as follows [21].

\[ V = \frac{E \times S}{AC} \]  

where  
\( V \) : Vulnerability  
\( E \) : Exposure  
\( S \) : Sensitivity  
\( AC \) : Adaptive Capacity

3. Results and discussion

3.1. Exposure

The level of exposure in this study comprises two variables, namely population density and the proportion of informal sector workers. Population density is related to the density of buildings or occupancy in each area. The higher the population density in an area, the more exposed it will be, because generally areas with high population density become the center of facilities and infrastructure for an area. The proportion of informal sector workers is one of the exposure variables in determining regional vulnerability based on social indicators in Pandeglang Regency. Livelihoods are generally associated with income levels the better a person’s livelihood is, the higher his income level will be.

Judging from the population density variable and the proportion of informal sector workers, the level of exposure of each sub-district in Pandeglang Regency will be obtained. Exposure was then divided into three classes: low, medium and high.

In table 4, you can see the distribution of the exposure areas in Pandeglang Regency. The area of moderate class exposure dominates as many as 17 districts or 48.57 %, then low class exposure is 13 districts or 37.14 % and high class exposure is as many as 5 districts or 14.28 %. In figure 1, the distribution of exposure interval classes is divided into three, namely low, medium and high. The distribution of areas with the highest class is in the southern part of Pandeglang Regency, one of which is Sumur sub-district, this is due to the proportion of population density in Sumur sub-district of 0.000133849 people per km² and the proportion of informal sector workers of 1.30. Meanwhile, the medium and low interval classes are scattered in the center and north of Pandeglang Regency.
One of the areas with low exposure is Koroncong District, located in the northern part of Pandeglang Regency, this is because the proportion of population density in Koroncong District is 0.270297542 people per km$^2$ and the proportion of informal sector workers is 0.04.

3.2. Sensitivity

We can define sensitivity as the internal condition of a system which shows the level of vulnerability to disturbances or obstacles. In this case the system in question is social vulnerability which is closely related to natural and human losses, the level of disturbance will directly or indirectly have an adverse impact on the entities that are in the system. In this case, the sensitivity analysis used in determining the sensitivity level of Pandeglang Regency is influenced by two variables, namely the Proportion of Vulnerable Populations and the Quality of the Building. The vulnerable age in this study comprised the elderly population, namely the population aged over 60 years and the population aged under five.

| Table 4. Number of districts based on exposure level in Pandeglang Regency. |
|-----------------|-----------------|-----------------|
| Exposure       | Number of districts | Percentage (%)  |
| Low            | 13               | 37.14           |
| Moderate       | 17               | 48.57           |
| High           | 5                | 14.28           |
| Total          | 35               | 100.00          |

Sources: Data Analysis, 2020

Figure 1. Map of exposure levels in Pandeglang Regency.
namely the population aged 0–4 years. The taking of these two variables is based on the alert level of the two variables above in dealing with a disaster. People who are members of the toddler and old age group will have obstacles or problems in movement compared to the non-population of the two variables above when a disaster occurs, this becomes a very important reference variable in calculating the level of sensitivity when a disaster occurs, considering the importance of individual movement when a disaster occurs. It happens, for that the two variables above will be very influential when a disaster occurs so that the more vulnerable age population, the higher the sensitivity level will be and vice versa. Apart from the Proportion of Vulnerable Populations, Building quality is also one variable used in measuring the level of sensitivity in Pandeglang Regency. The quality of the building has a very close relationship with the level of sensitivity considering the function of the building as a place to live. In this case, the number of non-permanent buildings will greatly affect the chance of losing a residence for the affected community. Therefore, the level of building quality will greatly affect the level of sensitivity of the area if it is hit by a disaster, where the more buildings in an area that are non-permanent will be directly proportional to the level of sensitivity.

A high proportion of non-permanent housing areas are generally found in the areas of Cibitung, Bojong, Menes and Cikedal. Several areas such as Cibitung, Sumur and Bojong which are coastal areas have a high level of sensitivity. This is because of most of the people who inhabit the area have low economic and social-cultural backgrounds and other areas that have the same high sensitivity qualifications.

There are two sensitivity variables taken in this study, comprising the proportion of the population of vulnerable age and the proportion of non-permanent houses. Based on these two variables, a sensitivity level can be obtained based on social indicators in Pandeglang Regency. The level of sensitivity is obtained by adding up the values of the variable proportion of the population with vulnerable age and the proportion of non-permanent houses by first doing the variable standardization. The sensitivity level is then divided into three, namely high, medium and low (table 5). The level of sensitivity which is dominated by the medium class is 14 districts or 40 %. Then the low class sensitivity level is 10 districts or 28.58 % and the high class sensitivity level is in 11 districts or only 31.42 % of the area of Pandeglang Regency. Figure 2 explains the distribution of districts based on the level of sensitivity. We generally find high and medium sensitivity areas in the south and middle of Pandeglang Regency. The high level of sensitivity is influenced by the high proportion of vulnerable age population and the high proportion of non-permanent housing. Then for low sensitivity areas are generally found in the western and eastern parts of Pandeglang Regency.

3.3. Adaptive capacity

Adaptation capacity is the ability of a system to deal with exposure [22]. The level of per capita income and the existence of community social institutions can be a more effective indicator in showing the adaptability of a system [23]. The variables in the adaptation capacity component, economic factors have a higher weight because economic factors are the most dominant factor in influencing the form of adaptation carried out by the community [24].

| Table 5. Number of districts based on sensitivity level in Pandeglang Regency. |
|--------------------------|-------------------|-----------------|
| Exposure                | Number of districts | Percentage (%)  |
| Low                     | 14                | 40              |
| Moderate                | 10                | 28.58           |
| High                    | 11                | 31.42           |
| Total                   | 35                | 100.00          |

Sources: Data Analysis, 2020
This study used three variables, namely the proportion of prosperous households, the proportion of the population who graduated from high school and the number of social institutions. Prosperous households allow faster recovery from the impact of disasters because they have more than adequate income to meet basic needs and are easier to access basic services, such as health and education services. The second variable in determining the level of adaptive capacity is the last level of education. From the level of education, it can measure the ability of a district to face and cope with disasters. In this study, the level of education was measured by the proportion of the population who graduated from high school. As for the third variable in determining the level of adaptive capacity, namely the number of social institutions in the community in each district of Pandeglang Regency.

Based on table 6, the level of adaptive capacity in Pandeglang Regency is dominated by the medium class, which is spread over 19 districts or amounting to 54.28%. Meanwhile, the adaptive capacity of the high class is 9 districts or 25.71% and the adaptive capacity of 7 districts or 20%.

The distribution of adaptive capacity interval classes is divided into three, namely low, medium and high. It can be seen in figure 3, the distribution of areas with the highest class is in the southwestern part of Pandeglang Regency and some are scattered in the north of Pandeglang Regency, one of which is Sumur sub-district, this happens because the proportion of the number of prosperous stairs is 0.02 and the level of education is 0.47 and the proportion of social institutions of 0.78. Meanwhile, the medium interval class is spread in almost all of Pandeglang Regency. And finally, for the low-interval class, it is spread in sub-districts in the northern part of Pandeglang Regency, one of which is Labuan sub-district, this is because the proportion of the number of welfare stairs is 0.03 and the level of education is 0.38 and the proportion of social institutions is 0.05.
| Exposure | Number of districts | Percentage (%) |
|----------|---------------------|----------------|
| Low      | 7                   | 20             |
| Moderate | 19                  | 54.28          |
| High     | 9                   | 25.71          |
| Total    | 35                  | 100.00         |

Sources: Data Analysis, 2020

Figure 3. Map of adaptive capacity in Pandeglang Regency.

3.4. Regional vulnerability based on social indicator

The vulnerability of an area is also related to the biological, geographic, social, economic, political, social, cultural and technological conditions or characteristics of a community in an area for a certain period which reduces the community’s ability to prevent, reduce, achieve readiness and respond to the impact of certain hazards [25]. Social vulnerability is a part of the result or impact of social inequality which is influenced by social factors or forms of vulnerability that danger or threaten various groups and which also govern their ability to respond [18]. Research by [26] states that the factors affecting social vulnerability are demographic factors, including population size, population density and population distribution based on age.

Regional vulnerability based on social indicators is calculated using the vulnerability formula from Turner et al. [20]. Areas that are vulnerable based on social indicators are divided into three,
The level of vulnerability that dominates is low vulnerability areas with a total of 25 sub-districts or 71.42%, while for moderate vulnerability areas there are 9 districts or 25.71% and high vulnerability areas only exist in 1 sub-district or 2.85%, namely in Cimanuk Districts.

Figure 4 provides information on the distribution of regional vulnerability levels based on social indicators in Pandeglang Regency, which generally has a low level of vulnerability. Several things can cause this low level of vulnerability. In addition to the level of exposure and sensitivity that is not too high and also balanced with a high level of capacity. Areas with a relatively high level of vulnerability are in the northern part of Pandeglang Regency, namely Cimanuk sub-district. The cause is high exposure such as population density of 0.454230786,

| Exposure | Number of districts | Percentage (%) |
|----------|--------------------|----------------|
| Low      | 25                 | 71.42          |
| Moderate | 9                  | 25.71          |
| High     | 1                  | 2.85           |
| Total    | 35                 | 100.00         |

Sources: Data Analysis, 2020

Figure 4. Vulnerability map based on social indicators in Pandeglang Regency.
the high proportion of informal sector workers is 0.13, then the high level of sensitivity with the high proportion of vulnerable age population and the number of non-permanent people but not balanced with a high level of adaptive capacity can be seen from the low proportion of wealthy households of 0.7891428 and the low proportion of SMA graduates amounting to 0.082239575. As well as the low number of social institutions, which number 44 also affects the high vulnerability in the Cimanuk sub-district. These factors affect the low ability of the population in this area to improve their quality of life so they are more easily exposed, more sensitive and less adaptive and have the opportunity to experience considerable losses and find it difficult to recover when hit by a disaster.

4. Conclusion

Based on the research results that have been described previously, the results show that the spatial pattern of social vulnerability to earthquakes and tsunamis in Pandeglang Regency based on social indicators is dominated by low vulnerability with a total of 25 districts or 71.42% spread over almost all areas of Pandeglang Regency. There are 9 districts or 25.71% of moderate vulnerability which are well known in the central to northern part of Pandeglang Regency. Meanwhile, there is only 1 sub-district or 2.85% of high vulnerability, namely Cimanuk District, which is in the northern part of Pandeglang Regency. This is due to the density of the population, the population of informal sector workers, the vulnerable age population and the buildings that are not permanent but have low welfare relationships, the number of social institutions that are as well as high school graduates. So that the earthquake or tsunami disaster in Pandeglang Regency, Cimanuk District will experience very high damage or loss.

We need a way to minimize the potential impact when a disaster occurs, especially in the northern part of Pandeglang Regency which has high vulnerability. One of them is by using social vulnerability data like this to be used as recommendations for taking early mitigation steps to reduce the level of social vulnerability. This high level of vulnerability can be minimized by increasing its adaptive capacity indicators such as increasing and optimizing the work of social institutions in each sub-district, so the existence of social assistance for underprivileged people is also needed as savings to meet their life needs and improve community education to reduce disaster risk. Other efforts that can be made to reduce high social vulnerability include regular updating of data when a disaster occurs, job training and job mapping to control the number of underprivileged people and transmigration to control population density.

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