An overview of physical and social vulnerability of high-risk coastal area after 14 years tsunami – a case study of Banda Aceh

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Abstract. On December 26, 2004, tsunami one of the deadliest disasters has occurred in Aceh. Many of the casualties apparently occurred as the result of lack of awareness of tsunami hazards among the communities. Banda Aceh city of Sumatra Island, Indonesia is one of the severely affected coastal areas surrounding the Indian Ocean. After 14 years, despite the remarkable disaster event, peoples tend to return to build their house near the coastal areas, particularly in Banda Aceh. The purpose of this study is to investigate the level of vulnerability of the coastal area of Banda Aceh more than a decade post-tsunami. This research uses GIS and spatial analysis for processing spatial data. The result shows that in 2016 and 2017 Banda Aceh has the highest physical vulnerability, which is 64% whereby one of the highest physical vulnerability was in Punge Ujong and the lowest was in Gampong Pie. On the other hand, in 2017 Banda Aceh has the highest social vulnerability, which is 69%. The area that has the highest social vulnerability was in Punge Ujong and the lowest was in Gampong Pande. Overall, the tsunami vulnerability level in Banda Aceh remains high, particularly in the coastal area. The result of the study implies that despite there is a collective memory of the tsunami of 2004, however, people tend to ignore the risk of living near the coastal areas. Actions in terms socialization on the risk and mitigation strategies should therefore be constitute in the development plan on the city level.

Keywords: tsunami, GIS, Banda Aceh, physical vulnerability, social vulnerability

1. Background

Earthquake and tsunami disasters that occurred in Aceh on 26th December 2004 which also known as Indian Ocean Earthquake and Tsunami was one of the greatest disasters that ever happens in history. More than 200,000 people become victims of these deadly disasters and destroyed infrastructure and coastal areas in Aceh, particularly the coastal area in western Aceh. During the disasters, Banda Aceh city was one of the locations suffered the most from the disasters, almost every village in Banda Aceh city were affected by the tsunami disasters.

After 14 years of tsunami disasters, Banda Aceh city has been rapidly developed. In fact, reflecting by past disasters, almost all regions in Banda Aceh city were on the red zone of tsunami disasters, particularly around the coastal area. After the disasters, the government of Aceh made a post-disaster housing located far from the coastal to minimize the risk if the disasters occurred since there are blueprint made by BRR (Badan Rehabilitasi dan Rekonstruksi) as the agency established by Indonesia government after the tsunami that prohibits to rebuild any buildings around 500 meters to 1 kilometer from the coastal area. However, in a few years, people especially who make living as a fisherman tend to rebuild their house in the same location as before tsunami around the coastal area. People who basically make living as a fisherman think they have to start again to make a living if it is not as a fisherman. So, they have to ignore the risk and start their life again in the same location if they still want to make a living as a fisherman. This brings questions about how vulnerability the city is after 14 years of the tsunami disasters since there are no signs of the impact of the disasters that ravaged the city in the past.
Reflecting from the tsunami disaster in Aceh, the Indonesian government also made laws about the disasters which is Law Number 24 of 2007[1] and guidance on making a risk map which is Chief Regulation Number 2 of 2012[2] contains several disasters that usually occurs in Indonesia. National Agency for Disaster Countermeasure both central and regionals was established with the purpose of giving and spreading information about disasters that occurs in each region. The establishment of the agency is expected to contribute to and reducing the risk of disasters occurring in Indonesia.

The Aceh government has made the risk map for the province-level which is known as Aceh Disasters Risk Map (ADRM) which was made by the Tsunami Disaster Mitigation Research Center (TDMRC) by the year 2011[3]. The risk map includes the type of disasters that usually occur in Aceh with an expectation to raise awareness for the people about the potency of disasters in each region. In general, there are two types of mitigation that could be used to reduce the impact of the tsunami there are by structural and non – structural [4]. In terms of structure it was from the building and in non - structural it was by giving basic information in terms of tsunami risk, education, or training to the community.

The previous studies about tsunami vulnerability have been conducted in recent years with various methods. Papathoma conducted researched about tsunami vulnerability in The Gulf of Corinth, Greece by identifying the tsunami inundation zone without looking at the tsunami source [5]. Putra conducted researched about mapping vulnerability in Mataram with the method by developing a combination index called Total Vulnerability Index (TVI), a combination of Physical Vulnerability Index (PVI), Social Vulnerability Index (SVI) and Economic Vulnerability Index (ECI) [6]. Fauziah has been conducted researched about tsunami risk in Banda Aceh City by using Chief Regulation Number 2 of 2012 and AHP method [7]. Sugiarti has been conducted researched about the physical and social vulnerabilities of tsunami in Banda Aceh city using technical guide for disaster risk in the city level made by BNPB and JICA in 2015[8][9].

This is semi-qualitative research since it was social research but to find the result it calculates by using statistical methods. The focus location of this research in Banda Aceh city. Banda Aceh city was divided into nine subdistricts which almost all villages in each subdistrict were affected by the tsunami. The making of the physical and social vulnerabilities in this research was using Geography Information System (GIS) and the data needed was secondary data which was acquired from Badan Pusat Statistik (BPS) also known as Statistics Indonesia, and data acquired from Badan Perencanaan Pembangunan Daerah (BAPPEDA) also known as Regional Development Planning Board from 2016 to 2018. The data that is needed for making the physical vulnerability map is the number of all the buildings in the region, religious building, education building, and health facility, while the data needed for making the social vulnerability map are the number of populations, disabled people, and poor people.

Based on the background research above, the outline of this research is to find out how vulnerable Banda Aceh city after 14 years of the tsunami but limited on physical and social vulnerabilities. The aim of this research to compare the physical and social vulnerabilities in Banda Aceh city from the past three years that were from 2016 to 2018. The research method conducted by Sugiarti was the most related since using the same method as this research.

1.1. Physical Vulnerabilities

Generally, a region is considered vulnerable to tsunami disaster based on the close proximity to the sea. In physical vulnerability, the component needed to determine the vulnerability is the building density, place of worship density, education building density, and health facility density located on the site of research. After all the components are acquired, there is a need to index the classification of each component. Index classification from each component gives the total weight of the physical vulnerability from the research location. The index classification can be seen in the next Table 1. The total score that was obtained by Table 1 will determine which village has the lowest or highest physical vulnerability.
Table 1. Physical vulnerability parameters [9]

| Component                  | Index Classification (Score) | Total Weight |
|----------------------------|------------------------------|--------------|
|                            | Low (0.333)                  | Moderate (0.666) | High (1.000) |
| **Building Density**       | < 150 per km²                | 150 – 1000 per km² | > 1000 per km² | 40% |
| **Place of Worship Density** | < 5 per km²                | 5 – 15 per km² | > 15 per km² | 20% |
| **Education Building Density** | < 2 per km²                | 2 – 6 per km² | > 6 per km² | 20% |
| **Health Facility Density** | < 3 per km²                | 3 – 9 per km² | > 9 per km² | 20% |

1.2. Social Vulnerabilities

The process of determining social vulnerability from the research location is the same as determining physical vulnerability. The component of social vulnerability is population density, sex ratio, disability ratio, poverty ratio, and age group ratio. After all data acquired, the next step is making the classification index like in the physical vulnerability process. The index classification can be seen in Table 2. The total score that was obtained by Table 2 will determine which village has the lowest or highest social vulnerability.

Table 2. Parameters of social vulnerability [9]

| Component                  | Index Classification (Score) | Total Weight |
|----------------------------|------------------------------|--------------|
|                            | Low (0.333)                  | Moderate (0.666) | High (1.000) |
| Population Density         | < 500 people/km²            | 500-4000 people/km² | > 4000 people/km² | 60% |
| Sex Ratio                  | > 80%                        | 80-60%       | < 60%            | 10% |
| Vulnerability Group        |                                 |               |                  |     |
| Poverty Ratio              | < 20%                        | 20-40%       | > 40%            | 10% |
| Disability Ratio           | < 20%                        | 20-40%       | > 40%            | 10% |
| Age Group Ratio            | < 20%                        | 20-40%       | > 40%            | 10% |

2. Results and Discussion

2.1. Physical vulnerability of Tsunami disasters from 2016 to 2018

Based on the research in 2016, the village in Banda Aceh that has the moderate score on physical vulnerability is Gampong Pie village in Meuraxa subdistrict with score of 0.4000. On the contrary, the village with the highest score on physical vulnerability is Punge Ujong village in Meuraxa subdistrict with score of 0.8667 The physical vulnerability map of Banda Aceh city in 2016 is shown at Figure 1.
Figure 1. Physical vulnerability level of Banda Aceh city in 2016

In 2017 the lowest physical vulnerability level of tsunami disaster is also in Gampong Pie village in Meuraxa subdistrict with score of 0.4000. Meanwhile, the highest in 2017 is Punge Ujong village in Meuraxa subdistrict with score of 0.9333.

Figure 2. Physical vulnerability level of Banda Aceh city in 2017 and 2018
In 2018, there are no changes in which villages have the lowest and the highest physical vulnerability level compared to 2017 as seen in Figure 2 since Gampong Pie village in Meuraxa subdistricts still having the lowest score of physical vulnerability with the score of 0.4000. Punge Ujong village in Meuraxa subdistricts also got the highest score of physical vulnerability with score of 0.8333.

2.2. Social vulnerability of Tsunami disasters from 2016 to 2018
There are several factors that affect social vulnerability in the tsunami disaster. The factors are population density, sex ratio, disability ratio, poverty ratio, and age group ratio. Based on the research in 2016 in Banda Aceh, the village that has the lowest score of social vulnerability Gampong Pande village in Kutaraja subdistrict with score of 0.4000, while the village with the highest score of social vulnerability is Punge Ujong village in Meuraxa subdistrict with the score of 0.8333. The social vulnerability map is shown in Figure 3.

In 2017 there is a change in social vulnerability level in Banda Aceh. The lowest score of social vulnerability was now changed to Gampong Pie village in Meuraxa subdistrict with score of 0.3333 while the highest score was still the Punge Ujong village in Meuraxa subdistrict with the score of 0.8333. The social vulnerability map is shown at Figure 4.
Figure 4. Social vulnerability level of Banda Aceh city in 2017

As in 2017, there is also a change in 2018 based on the previous research on the social vulnerability level in Banda Aceh. The lowest score of social vulnerability now in Gampong Pande village in Kutaraja subdistrict with the score of 0.3333 while the highest score is the Merduati village in Kutaraja subdistrict with the score of 0.8333. The social vulnerability map is shown in Figure 5.

Figure 5. Social vulnerability level of Banda Aceh city in 2018

2.3. Comparison between physical and social vulnerabilities in Banda Aceh from 2016 to 2018
The analysis result of the last three years in Banda Aceh is at the moderate-high level. Factors that most influence the physical vulnerability in Banda Aceh are the building density and education building density. The percentage comparison table of physical vulnerability of the tsunami disaster in Banda Aceh city of the last three years is shown in Table 3.

Table 3. The percentage comparison table of physical vulnerability of tsunami disaster in Banda Aceh city of the last three years.

| Year | Low | Moderate (%) | High |
|------|-----|--------------|------|
| 2016 | -   | 36           | 64   |
| 2017 | -   | 36           | 64   |
| 2018 | -   | 47           | 63   |

Based on Table 3 it can be seen that between 2016 and 2017 the percentage of physical vulnerability in Banda Aceh is 36% for the moderate level and 64% for the high level. On the contrary in 2018 the number is 47% for the moderate level and 63% for the high level. This shows that Banda Aceh is still at the high physical vulnerability as the higher building density in any location makes the physical vulnerability higher. This is might be due to the increase of housing complex building in several villages in Banda Aceh in the last three years.

On the other side, the social vulnerability of the tsunami disaster in Banda Aceh in 2016 was moderate-high. But, in 2017 and 2018 there is also a low vulnerability level in Banda Aceh. Based on the research, 2017 has the highest vulnerability compared to 2016 and 2018. The comparison can be seen in Table 4.

Table 4. The percentage comparison table of social vulnerability of tsunami disaster in Banda Aceh city of the last three years.

| Year | Low | Moderate (%) | High |
|------|-----|--------------|------|
| 2016 | -   | 43           | 57   |
| 2017 | 4   | 27           | 69   |
| 2018 | 5   | 26           | 69   |

Based on Table 4 it can be seen that the increase in the percentage of the social vulnerability of tsunami disaster in Banda Aceh. In 2016 the level of social vulnerability in Banda Aceh is moderate-high. But in 2017 and 2018 it changed to low – high social vulnerability level. Comparing to the last three years for social vulnerability level, it can be seen that Banda Aceh in 2017 has the highest social vulnerability which is 4% for the low level, 27% for the moderate level, and 69% for high level. In the social vulnerability level, the influence was from the population density and age group ratio.

3. Conclusion
Based on the research findings it was noted that the tsunami disaster vulnerability in Banda Aceh is considered at a moderate-high level even after a decade of the tsunami. Village in which vulnerability is at a moderate-high level generally is the village that suffered severe destruction when the tsunami occurred. Despite the tsunami disaster has passed for 14 years, people tend to ignore the risk of living near the coastal areas. Actions in terms of socialization on the risk and mitigation strategies should therefore constitute in the development plan on the city level. Due to the limitation of data and only comparing for the three recent years that is 2016 to 2018, the result is not very clear which has the lowest and highest physical vulnerability and social vulnerability level in Banda Aceh city after the tsunami. For further research, it should be carried
out by comparing every two or five years after the tsunami until recent years to give a better result which village has the lowest or highest vulnerability level after the tsunami.

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