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A Preliminary Study on Tsunami Disaster in Yogyakarta: Identification of Vulnerability Order and Components

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Abstract

A tsunami is a disaster that can be hardly estimated. It is a significant concern UN since more than 60% of the world's population lives in coastal areas prone to tsunamis, including Indonesia. The county community with complex and dynamic plate requires mastering of mitigation strategies as a tsunami preventive effort. Understanding the vulnerable elements in risky areas is critical. However, the magnitude of potential disasters cannot be minimized. This study analyzes the tsunami vulnerability in Bantul, Special Region of Yogyakarta (DIY). The analysis was based on a description of assessment parameters such as land use, the physical condition of the area, social conditions, and availability of infrastructure. The results show that social vulnerability had the most significant impact.

Keywords: Vulnerability, Tsunami, Bantul, DIY

1. Introduction

A tsunami refers to waves that are faster, taller, and stronger than wind or storm surge (Chen & Cheng, 2016; Rangel-Buitrago *et al.*, 2020). It has frequently occurred in the last decade, damaging coastal structures (Nandasena *et al.*, 2012). Its incidencet on a large scale is relatively less frequent compared to hydrometeorological disasters.The associated waves are unpredictable because they are caused by sudden significant volcanic displacements, initially triggered by earthquakes, landslides, volcanic eruptions, or meteors (Al-Faesly *et al.*, 2012).

On December 26, 2004, a tsunami disaster was triggered by the magnitude of an Earthquake with a strength of 9.1 Ritcher Scale (SR) in the Indian Ocean. The maximum height of the waves was 30 meters, causing more than 200,000 deaths and massive destruction of property in more than ten countries bordering the Indian Ocean (Grilli 2007, Leonard & Lucinda, 2014; Iverson & Prasad, 2007; Roshan *et al.*, 2016). On February 27, 2010, a tsunami disaster was triggered by an 8.8 magnitude earthquake of the coast of Chile. The waves reached local run-ups of 29 meters high on coastal cliffs (Fritz, 2010). On March 11, 2011, a magnitude 9.0 earthquake stroked near the coast of northeastern Japan and swept along the coast, penetrating the land with a maximum height of 40 meters (Yeh *et al.*, 2013). On September 16, 2015, an 8.3 magnitude earthquake occurred off Chile's central coast and triggered a tsunami with a maximum runoff height of 13 meters (Contreras-Lopez *et al.*, 2016). In Thailand, the dock plates at the port of Khao Lak and the fishing port of the Ban Nam Kem deck were severely damaged by the uplifted pressure due to the Indian Ocean tsunami of 2004 (Ghobarah *et al.*, 2006). The same incident occurred in Japan and damaged the Sendai port in the Tohoku region during the 2011 tsunami (Suppasri, 2012).

Based on the risk analysis conducted by the National Disaster Management Agency (BNPB) in 2012, four major areas have high risk and probability of tsunami, including Mentawai, Sunda Strait, and southern part of Java, Megathrust south of Bali and Nusa Tenggara, and northern Papua Region. Of the four areas, the South Java Coast or *Pansela,* has the largest population (BNPB, 2012). Due to a large number of residents in this region, the spatial planning along the South Coast of Java should be based on coastal area disaster mitigation.

The coastal area of the Bantul Regency is prone to tsunami because it is a low lying area designed as one of the National Strategic Tourism Area (Hadipour *et al.*, 2019; McGuire, 2020). The existence of South Cross Road (JJLS) increase the strategic value of the coastal areas. It connects the southern coast of Java Island to the coast of Bantul Regency. Also, the new airport development plan in the coastal area of the Kulonprogo Regency is next to the Regency, which is integrated with National Tourism Strategic Area (KSPN) Borobudur and road along JJLS. Generally, airports are encouraged to support the development of KSPN Borobudur and surrounding areas. This is stated in the National Tourism Development Master Plan 2010-2025. Figure 1 shows the DIY Southern Coast Strategic Region.

The implementation of spatial planning should be carried out comprehensively, holistically, well-coordinated, integrated, effective, and efficient, focusing on political, economic, social, culture, defense, security, and environmental sustainability (Ibrahim & Hegazy, 2013). Spatial planning needs to be based on the system approach, main function, administration, activity, and strategic value areas, taking into account the disaster factor (Muta'ali, 2014).

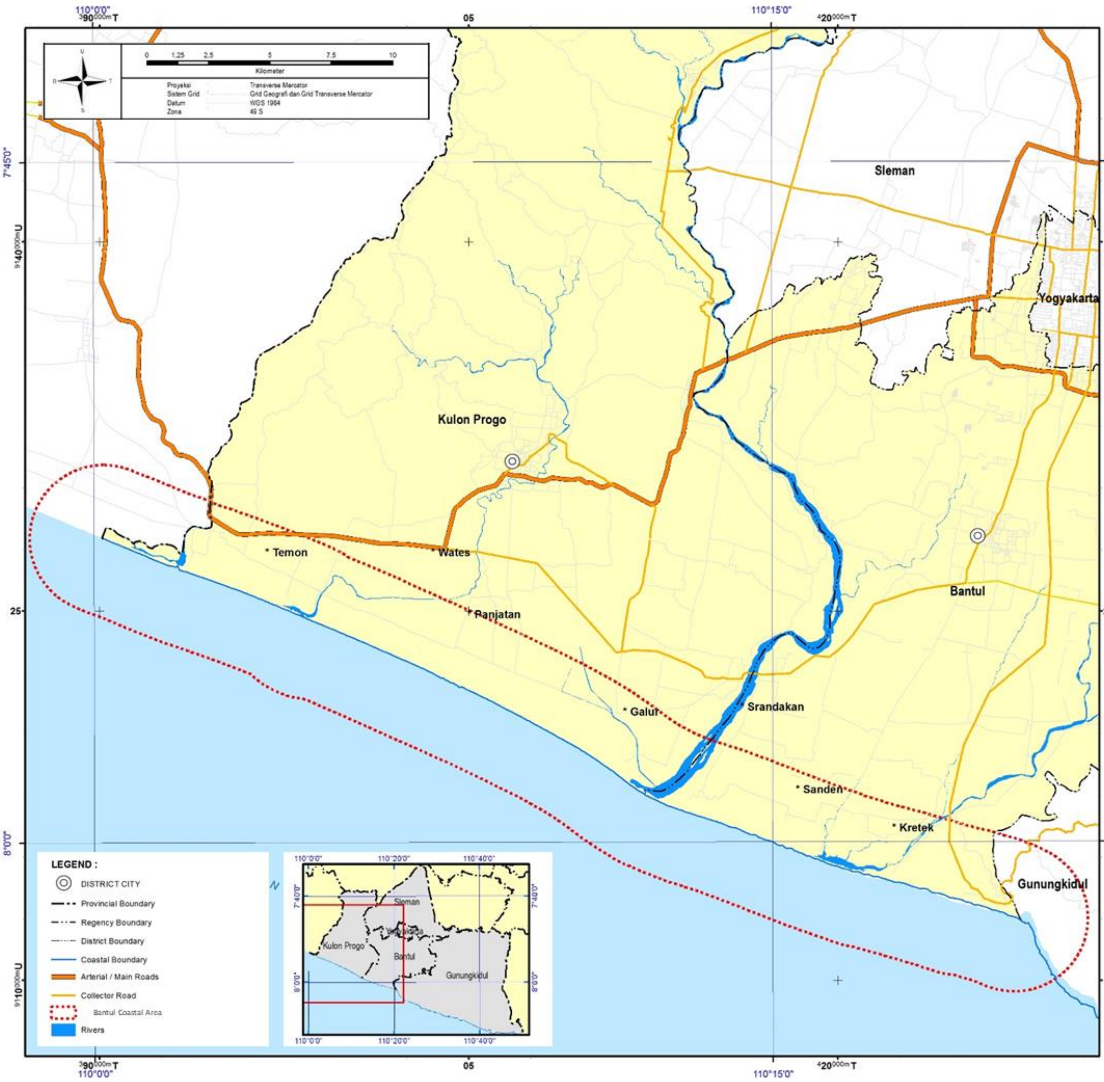

Figure 1. KSPN Pansela Yogyakarta Area.
Source: Government Regulation Number 50 the Year 2011 Concerning Master Plan of National Tourism Development Year 2010 - 2025.

The development plan of the southern coastal region, including the Bantul area, has encouraged unity in the spatial planning following the risk of the tsunami disaster (Balasundareshwaran *et al*., 2020). This study analyzes the tsunami vulnerability orderbased on the assessment parameters, including land use, the physical condition, social state,and infrastructure availability.

2. Methods

The identification of dangerous elements in the disaster-prone area is part of mitigation. This aspect was investigated by Tanaka, (2008); Tanaka *et al*., (2010); Liyanage & Lee, (2012); Freire *et al*., (2012); & Shibayama *et al*., (2012). In this research, the risky component was considered a significant factor in mitigation since the magnitude of the disaster cannot be reduced. The assessment of the damage was conducted by identifying and calculating the vulnerability order, including land use, the physical and social condition of the area, availability of infrastructure, and economic. The unit of analysis was the village administration. Theidentification of elements at risk within the tsunami danger zone, including physical, social, and economic elements, is a significant step in determining vulnerability order. The parameters used are based on the National Disaster Management Agency (BNPB) Regulation No. 2 of 2012 and several previous studies. The research flows as follows.

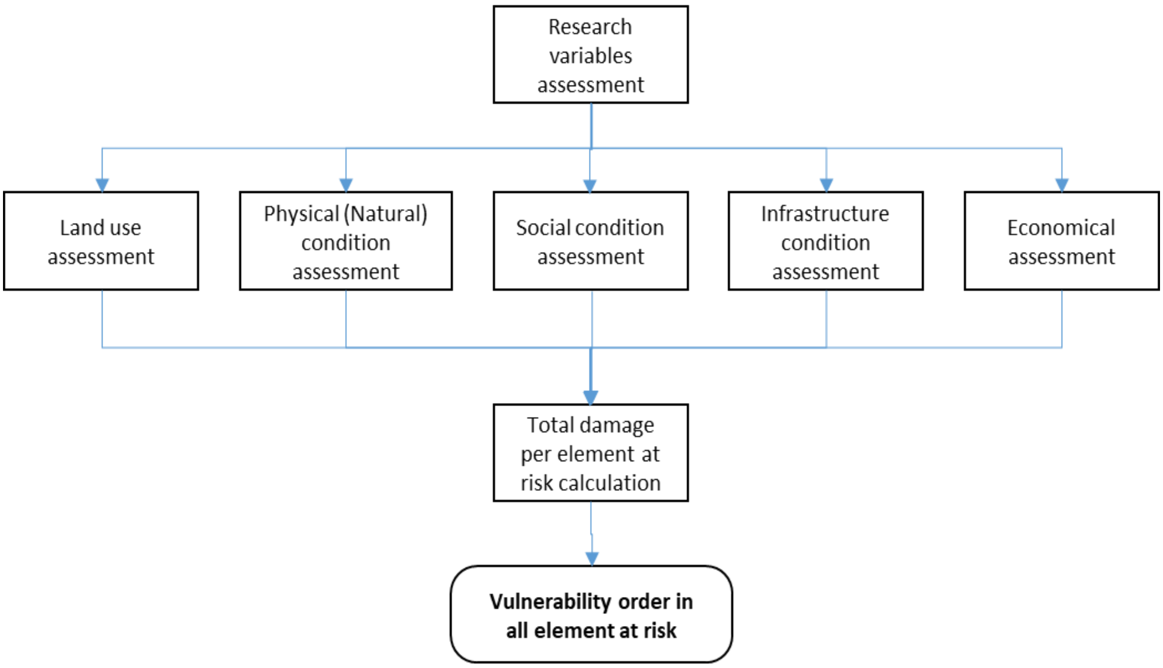

Figure 2. Research Flow

3. Results and Discussion

Indonesia is a country prone to the tsunamis, especially in the coastal area that directly faces the meeting layer of Eurasia Plate, Indo-Australia, and the Pacific, including the western part of Sumatra Island, the southern part of Java Island, Nusa Tenggara, the northern part of Papua, Sulawesi, Maluku, and the eastern part of Kalimantan Island (BMKG, 2012; McGuire, 2020).The common disaster occurringis a close-range tsunami of around 200 km from the earthquake epicenter. Local tsunamis can be caused by earthquakes,slide, and volcanic eruptions (BMKG, 2012). Table 2.1 depicts the tsunami history occurring in Indonesia.

Table 1. Significant Tsunami Event in Indonesia

No	Year	Location	Magnitude	Total Victims
1	1883	Krakatau Volcano	-	36,000
2	1833	West Sumatera, Bengkulu, and Lampung	8.8	unreported
3	1938	Kal Island, Bangka	8.5	unreported
4	1967	Tinambung	-	58
5	1968	Tambu, Southeast Sulawesi	6.0	200
6	1977	Sumbawa	6.1	161
7	1992	Flores	6.8	2,080
8	1994	Banyuwangi	7.2	377
9	1996	Toli Toli	7.0	9
10	1996	Biak	8.2	166
11	2000	Banggal	7.3	50
12	2004	Nangro Aceh Darussalam	9.0	250,000
13	2006	Pangandaraan	7.2	>600
14	2010	Mentawai	7.7	>400

Source : Mardiatno (2008)

The greatest tsunami in the history of Indonesia occurred in Aceh on December 26, 2004. It started by the earthquake magnitude of 9.3 SR, which caused a strong shock and fault, stretching from Aceh to Andaman. The tsunami was attributed to the earthquake with huge losses and 250,000 deaths (Mardiatno, 2008). Almost all of the tsunami disasters led to material losses and claimed many lives. According to Table 2.1, the most recent tsunami occurred in October 25th 2010 in Mentawai Island, West Sumatra. It started with an earthquake of magnitude 7.7 SR, followed by tsunami waves of 3-10 meters. This caused destruction of 77 villages and more than 400 deaths (Mardiatno, 2008).

Bantul Regency has ahigh vulnerability because it directly faces the Indian Ocean. Additionally, the coastal typology tends to be flat (Trihatmoko, 2017; McGuire, 2020). When a tsunami strikes, it is likely to damage the physical and social aspects, as well as the existing infrastructure.

Social vulnerability should be the first concern since it relates to the number of people affected (Koroglu *et al*., 2019; Liu *et al*., 2020; Malherbe *et al*., 2020). The readiness of every resident in the face of disasters significantly affects vulnerability. In case the community is ready to face any disaster, the severity can be reduced.

Social vulnerability is the ability to recover from the impact of natural disasters based on age and sex group of the populations (Dawyer, 2004. in Zulkarnaen, 2012). It is based on the understanding of the disaster and the resulting conditions. This includes the ability to evaluate when it occurs and the recovery process. The population of women, children, and the elderly is considered the most vulnerable (Subarkah, 2009).

Based on the Law of the Republic of Indonesia Number 24, 2007 on Disaster Countermeasure, the vulnerable groups include infants, toddlers, and children of pregnant and lactating mothers, the disabled and the elderly. According to Subarkah. (2009), the components used in calculating social vulnerability include age and sex groups. The vulnerability is assessed based on an understanding of current and post-disaster conditions based on the evacuation capability. In this assessment, the population of women, children, and the elderly are targeted.

Table 2 shows the population in Bantul Regency, which can be potentially affected in case the tsunami strikes. This data includes the number of people living in the district directly facing the Indian Ocean. Population density also affects the vulnerability of a region. Table 2 shows the Pandak District has the highest population and density.

Table 2. Population and Population Density based on District which directly facing the Indian Ocean in Bantul Regency

District	Population	Population Density
Srandakan	29,130	1,590
Sanden	30,114	1,300
Kretek	30,111	1,125
Pundong	32,321	1,365
Bambang Lipuro	38,206	1,684
Pandak	48,950	2,014

Source : Statistics of Bantul Regency (2016)

Economic vulnerability is the risk of damage, negative impact, or external shock resistance due to unexpected events (Koroglu *et al*., 2019; Liu *et al*., 2020). The calculation losses can be a good indicator of the economy (Gulllaumom, 1999, in Zulkarnain 2012).

Physical vulnerability is the last aspect describing the extent of damage to physical infrastructures exposed to hazards, such as residential buildings (Ishtiaque *et al.,* 2019). It affects the local community's structural readiness and the condition of structures (Prasstiya, 2013). The main Physical vulnerability in Bantul Regency include JJLS and the existence of Airport .

The most important thing to do in adjusting the development of risk management strategies is to assess vulnerability to potential tsunami damage in the proper order (Lantz *et al.*, 2020). However, vulnerability assessment has never been formulated in an appropriate legal document. Building vulnerability means calculating thestructures' capacity in the horizontal pressure of tsunami flows and its susceptibility to water (Dall'Osso *et al.*, 2009; Koroglu *et al.,* 2019).

4. Conclusion

In this study, the ranking of the element at risk involves social, economic, and physical vulnerabilities. Social vulnerability is considered to be the most powerful aspect associated with detailed and varied subcomponents. The economic vulnerability comes second in terms of the economic conditions of a society. It is closely related tocommunities'specific capacity to survive. Physical vulnerability is rated last since rebuilding of infrastructures is easier than social or economic development.

Conflict of Interest

The authors declare that there is no conflict of interest with any financial, personal, or other relationships with other people or organizations related to the material discussed in the article.

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