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MULTI-HAZARD SUSCEPTIBILITY ANALYSIS OF BANTUL REGENCY

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ABSTRACT

The Bantul Regency area has varied landform characteristics so it is susceptible to several disasters such as landslides, earthquakes, and tsunamis. The purpose of this study was to analyze the level of susceptibility to landslides, earthquakes, and tsunamis in Bantul Regency. The method used to determine the level of susceptibility of the Bantul Regency is tiered weighting. The data used are the National Digital Elevation Model (DEM), geological and geomorphological maps of Yogyakarta, Indonesian earth map, Yogyakarta soil type map, and rainfall data. The results of this study indicate that the susceptibility of landslides in Bantul Regency tends to be high in areas with hilly reliefs, while flat areas tend to be safe. Earthquake disasters tend to be susceptible in areas that are close to faults and have high slopes. The Bantul Regency area which is close to the coastline and has a high elevation tends to be susceptible to tsunami disasters. These results can be used as planning material to increase the capacity of Bantul Regency to deal with those three disasters.

Keywords: *multi-hazard susceptibility, landslide, earthquake, tsunami, Bantul Regency*

INTRODUCTION

Natural disasters are threats as well as a potential that are faced by every region on Earth (Sakti, A. D, et al., 2021). Geographical, demographic, sociological, and historical conditions are some of the factors that cause natural disasters (Yulianto, et al., 2021). One of the disaster studies is susceptibility. According to Law of the Republic of Indonesia Number 24 of 2007 concerning Disaster Management and National Disaster Management Agency (Badan Nasional Penanggulangan Bencana, 2012), susceptibility is a geological, biological, hydrological, climatological, geographical, social, cultural, political, economic, and technological condition or characteristic in an area for a certain period, which can reduce the ability to prevent, achieve readiness, and reduce the ability to respond to the adverse effects of a hazard. Susceptibility provides an overview of a disaster's threat to an area's sustainability.

Indonesia is one of the areas with high disaster susceptibility. The activity of three major tectonic plates, namely the Indo-Australian, Eurasian, and Pacific plates creates a series of volcanoes along Sumatra in the southeast, Java, Bali, Nusa Tenggara, north of Sulawesi to Maluku and Papua. In addition, tectonic activity forms faults on islands in Indonesia. This condition creates the potential for a geological disaster in Indonesia. Based on data processed by the National Disaster Management Agency from 2005 to 2015, 22% of geological disasters occurred (BNPB, 2016). Although the number of geological disasters is not as many as

meteorological disasters, the impact caused by these disasters is recorded to be greater.

One of the areas in Indonesia that has several disaster susceptibilities is Bantul Regency. Bantul Regency consists of several landforms: structural, fluvial, marine, solutional, volcanic, and aeolian. In addition, Bantul is located north of the confluence of the Indo-Australian Plate and the Eurasian Plate and has an active fault, namely the Opak Fault, which is trending northeast-southwest (Pandita, et al, 2016). The climate in Bantul is tropical with high rainfall intensity every year. These diverse landscapes as well as geological and climatological conditions hold many threats and various types of disaster susceptibility. Bantul has several disaster susceptibilities, including landslides, earthquakes, and tsunamis.

Landslide disaster is a type of mass movement of soil, rock, or a mixture of both down a slope that disrupts the stability of the soil or rock constituents (Irawan et al., 2020). Landslides occur due to complex interactions between various factors including geology, geomorphology, hydrology, rainfall, and land use. Landslides become active due to disturbances on the slopes which have an impact on reducing shear strength and/or increasing shear stress on the soil simultaneously (Andriyanto, 2020). Severe landslides occurred in Bantul Regency after Tropical Cyclone Cempaka on November 28-29, 2017 (Aminatun & Anggraheni, 2018).

The tectonic earthquake on May 27, 2006 in Bantul Regency became one of the disasters with the largest damage and casualties ever recorded in Indonesian history. The earthquake was caused by the Opak fault movement, resulting in an earthquake with a magnitude of 6.4 Mw. In addition to the Opak fault activity, earthquakes in Bantul can occur due to the subduction activity of the Indo-Australian and Eurasian plates which have a movement speed of 7 cm/year (Hadi, 2016). This movement can cause subduction earthquakes, namely earthquakes that are near the confluence of oceanic plates that sink under the continental plates (Pratama, 2020). Large magnitude subduction earthquakes can cause seawater masses to be sucked into gaps or faults. Then, the seawater mass is thrown back after the fault reaches equilibrium. The mass of water that was thrown in large quantities caused large waves that hit the coast, known as tsunamis (Basith dkk. 2012).

Considering the magnitude of the potential disaster susceptibility in Bantul Regency and the large impact that can harm humans, it is necessary to take disaster preparedness actions. Identifying and mapping susceptible areas should be carried out as an early anticipation step for disasters that may occur. Therefore, this study was conducted to analyze the level of susceptibility to earthquakes, tsunamis, and landslides in Bantul Regency.

RESEARCH METHOD

The research method used in multi-hazard susceptibility in Bantul Regency is a quantitative descriptive method. Multi-hazard analysis was carried out using a weighted tiered weighting method to determine the susceptibility of disasters in Bantul Regency, such as earthquakes, tsunamis, and landslides. Each disaster has different parameters. Data of each disaster parameter were obtained from primary and secondary data, such as DEMNAS, Yogyakarta geological map, Rupa Bumi Indonesia map of Bantul Regency, soil type map of Bantul Regency, and CHRS Data Portal. The weighting process used ArcGIS software to overlay each disaster parameter and calculate the score of each parameter to obtain a susceptibility map for several disasters that have the potential to occur in Bantul Regency.

Disaster Parameters

Table 1. Earthquake susceptibility parameters

No.	Parameter	Classification	Score	Weight
1	Geology	Andesite, granite, diorite, metamorphic, volcanic breccia, agglomerate, sedimentary breccia, conglomerate	1	3

		Sandstone, coarse tuff, siltstone, arkose, greywacke, limestone.	2	
		Sand, silt, mudstone, marl, fine tuff, shale.	3	
		Clay, silt, organic slab, peat.	4	
2	Slope (%)	0 - 7	1	3
		7 - 30	2	
		30 - 140	3	
		> 140	4	
3	Geological Structure	Far from fault zone (>1000m)	1	4
		Close to the fault zone (100 - 1000 m from the fault zone)	2	
		At the fault zone (< 100 m from the fault zone)	4	

Table 2. Tsunami susceptibility parameters

No.	Parameter	Classification	Score	Weight
1	Distance from shoreline (m)	<556	1	30
		557-1.400	2	
		1.401 - 2.404	3	
		2.405 - 3.528	4	
		>3.528	5	
2	Distance from river (m)	0 - 450	1	15
		451 - 900	2	
		901 - 1.350	3	
		1.351 - 1.800	4	
		1.801 - 2250	5	
		>2250	6	
3	Land elevation (m)	0 - 5	1	30
		6 - 10	2	
		11 - 15	3	
		16 - 20	4	
		> 20	5	
4	Slope (%)	0 - 2	1	25
		2 - 6	2	
		6 - 13	3	
		13 - 20	4	
		20 - 55	5	
		>55	6	

Table 3. Landslide susceptibility parameters

No.	Parameter	Classification	Score	Weight
1	Annual precipitation (mm/year)	<1000	1	30
		1000 - 2000	2	
		2000 - 2500	3	
		2500 - 3000	4	
		>3000	5	
2	Slope (%)	<8	1	15
		8 - 15	2	
		15 - 25	3	
		25 - 45	4	
		> 45	5	
3	Landuse	Forest/vegetation and water bodies	1	15
		Garden and shrub mix	2	
		Irrigated plantation and rice fields	3	
		Industrial and residential areas	4	
		Vacant land	5	
4	Soil type	Lithosol	2	20
		Grumusol	3	
		Regosol	4	
5	Rock type	Agglomerate, Layered Limestone, Marl, Volcanic Breccia, Agglomerate, Tuff, Andesite Lava Flow, Silt, Clay, Mud, Sand, Gravel, Gravel, Shallow	2	20
		Sand, Gravel, Tuff, Tuff lapilli, Lapilli Rock, and Pumice breccia	3	

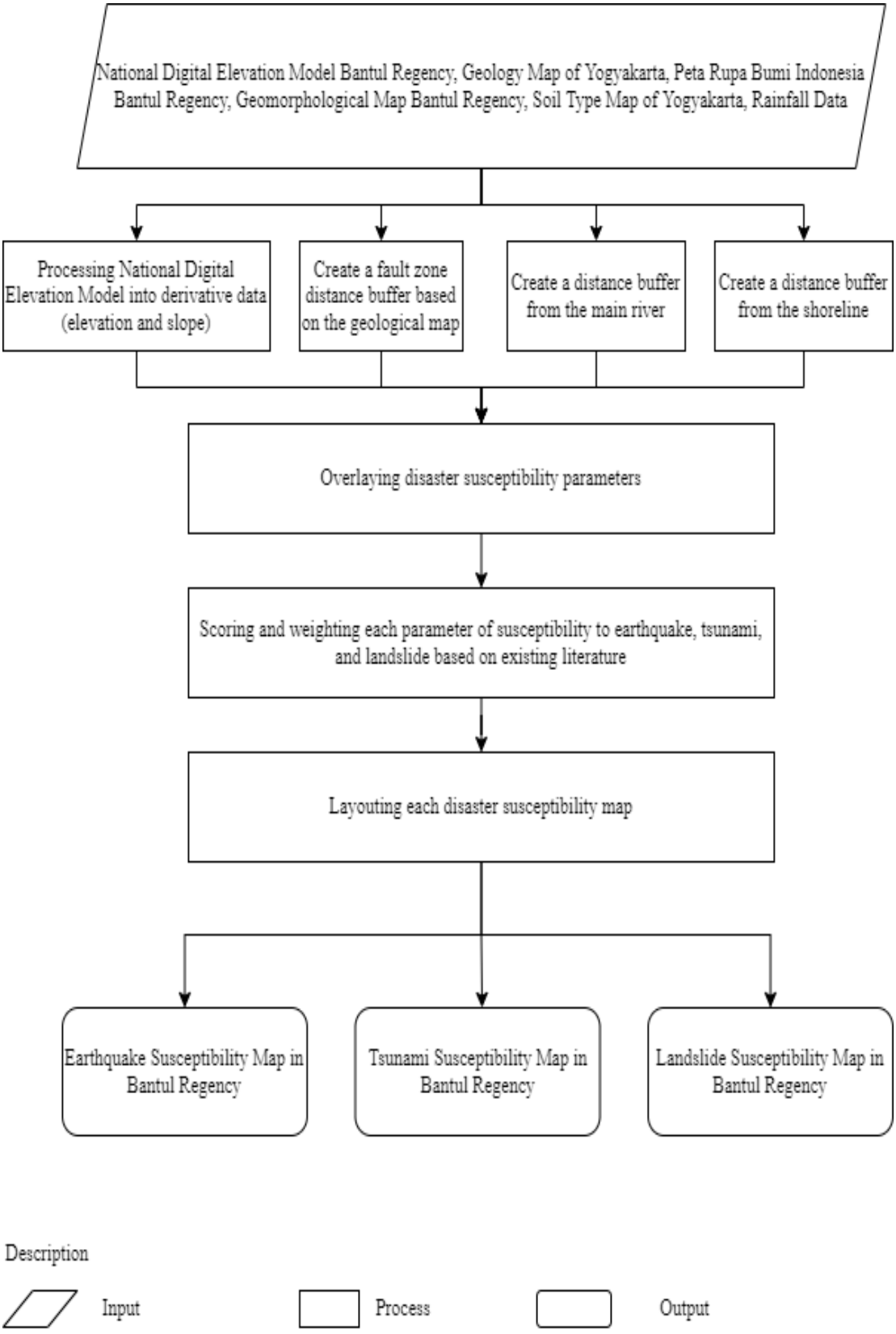

Figure 1. Flow Diagram

RESULTS AND DISCUSSION

Landslide Susceptibility

Landslides can cause material losses such as damage to roads, houses, public facilities, and agricultural land that impact social and economic conditions (Rahayu, et al., 2019). Therefore, it is essential to carry out a landslide susceptibility analysis by making a landslide susceptibility map. Landslide susceptibility maps are needed as a basis for spatial planning, land use and disaster mitigation (Rahma, 2018). The classification of landslide susceptibility in Bantul Regency is divided into five classes: very safe, safe, quite susceptible, susceptible, and very susceptible.

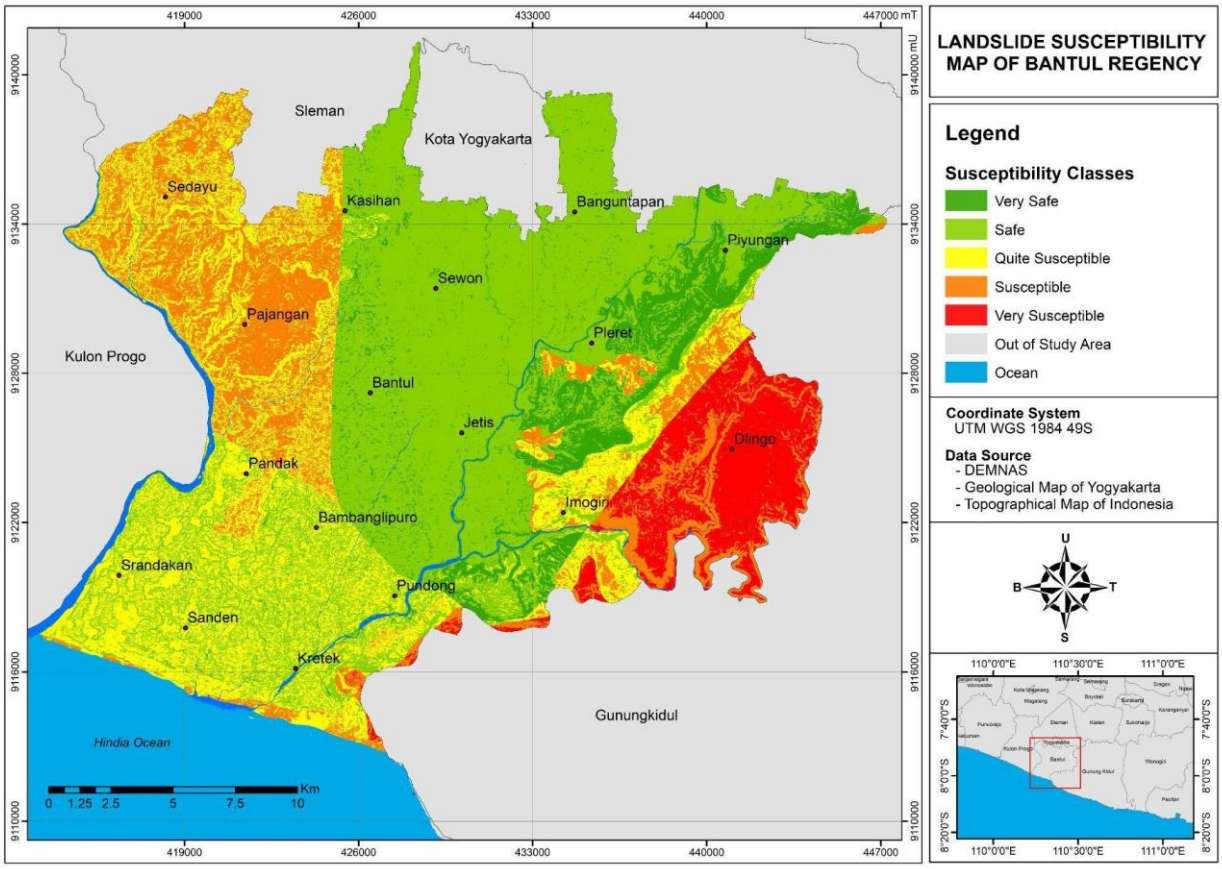

Figure 2. Landslide Susceptibility Map of Bantul Regency

The most susceptible class is located in the eastern region of Bantul Regency, precisely in Dlingo District. The area is a fractured structural hill of the Sambipitu and Wonosari formation ecoregions. Both ecoregions have relatively rough relief because they are dominated by hilly landforms of structural faults which significantly affect slope parameters. This parameter is one of the factors that trigger landslides due to the influence of the earth's gravity. The steeper the slope, the easier it is for mass movement to occur. The susceptibility to landslides will increase during the rainy season because the soil mass will be heavier and the soil will be easier to move. In all areas of Bantul Regency, the annual precipitation is >3000 mm/year which is included in the highest score. Inappropriate land use and the high intensity of human activity in changing land use will increase the risk level in landslide-prone areas. Land use in these two ecoregions has a score of 3-5. The type of soil in this very susceptible class area is lithosol which is slightly sensitive to landslides. However, the soil type does not have much effect due to the other parameters having a high score.

The west dominates the susceptible class to the northwest and is slightly distributed in the eastern region of Bantul Regency. These areas are included in the S2L-Tmps, S2P-Tmss, and V3-Qmi ecoregion units with the dominant landform in the form of fractured structural hills. The soil type that dominates this area is lithosol with rock types

in the form of agglomerates, layered limestone, tuff lapilli, and lapilli. Land use in this area is dominated by industrial and residential areas, so it has a score of 4. This is because the construction of intensive settlements and not paying attention to the slope can trigger additional landslide incidents (Khosiah and Ariani, 2017). The slope parameter in this area has a score of 3-5. Based on the score of these parameters, supported by a high rainfall factor, this area has a high enough total score.

Quite susceptible classes are located in several parts of Bantul Regency, which are the western, eastern, and southern regions. The area is located in the ecoregion units F2-Qmi, S2P-Tms, S2L-Tmps, S2P-Tmss, and V3-Qmi with 2 types of landforms: Volcanic Fluvio Plain of Young Merapi Volcanic Deposits and Structural Fault Hills. There are two soil types in this area, that is lithosol and grumosol. The rock types in this area are dominated by sand, gravel, and tuff. The land use in this area is dominated by industrial and residential areas with little vacant land in some parts. According to Karnawati (2003) in Sungkar, et al (2017), residential and vacant land increase the soil erodibility so that it becomes more sensitive to landslides. However, the slope parameter in this area is dominated by a slope of <8°. Therefore, the total score for all parameters is neither too high nor too low.

Safe and very safe classes tend to be in the central areas of Bantul Regency, such as Sewon, Banguntapan, Jetis, Pleret, and Piyungan. The area is included in the F2-Qmi ecoregion. The very safe class has a lithosol soil type. On the other hand, the safe class has regosol soil types that are more sensitive to landslides than lithosols. The rock types in this area are dominated by volcanic breccia, agglomerates, sand, gravel, and tuff. Land uses in this class area are dominated by a score of 4, which is industrial and residential areas. This area has a smooth relief with a flat slope, so it makes this area insensitive to landslides. The slope is one of the most influential parameters of landslide susceptibility (Abrauw, 2017). Therefore, this slope parameter causes the total score in this area to have a low to meager value.

Earthquake Susceptibility

An earthquake is an enormous shock that spreads to the earth's surface due to disturbances in the lithosphere. Tectonic earthquakes occur due to the release of energy due to fault shifts or elasticity in the area where the oceanic plate collides with the continental plate (Sungkawa, 2016). Therefore, earthquake susceptibility is strongly influenced by the geological structure, constituent materials, and level of the slope of an area. Bantul Regency is one of the areas located on the southern coast of Java Island, so it is close to the subduction zone of the Eurasian Plate and the Indo-Australian Plate. Complex tectonic conditions have caused Yogyakarta and surrounding areas (including Bantul Regency) to become seismically active areas with a fairly high seismic frequency (Wibowo and Sembri, 2017). Bantul Regency is crossed by a large fault called the Opak Fault on the east side of Bantul Regency. The existence of the Opak fault increases the level of earthquake susceptibility in the Bantul Regency.

Processing of earthquake susceptibility data from several parameters, namely geological materials, slopes, and geological structures in Bantul Regency. The geological material that composes an area will affect the durability of the material and the stability of the slopes, which can affect the durability of the buildings on it in the event of an earthquake (Marsell, 2013). Geological material reflects the physical properties of rocks in an area that shows the strength of these rocks in receiving pressure. Strong rock will be more stable against the possibility of landslides and subsidence during earthquake shocks (Ridha, et al., 2021). The slope describes the level of slope stability against the possibility of landslides and soil and rock collapse during an earthquake disaster (Ridha, et al., 2021). Geological structure is the presence of faults

in an area that can cause earthquakes. Areas close to the fault will have a higher earthquake susceptibility compared to areas further from the fault.

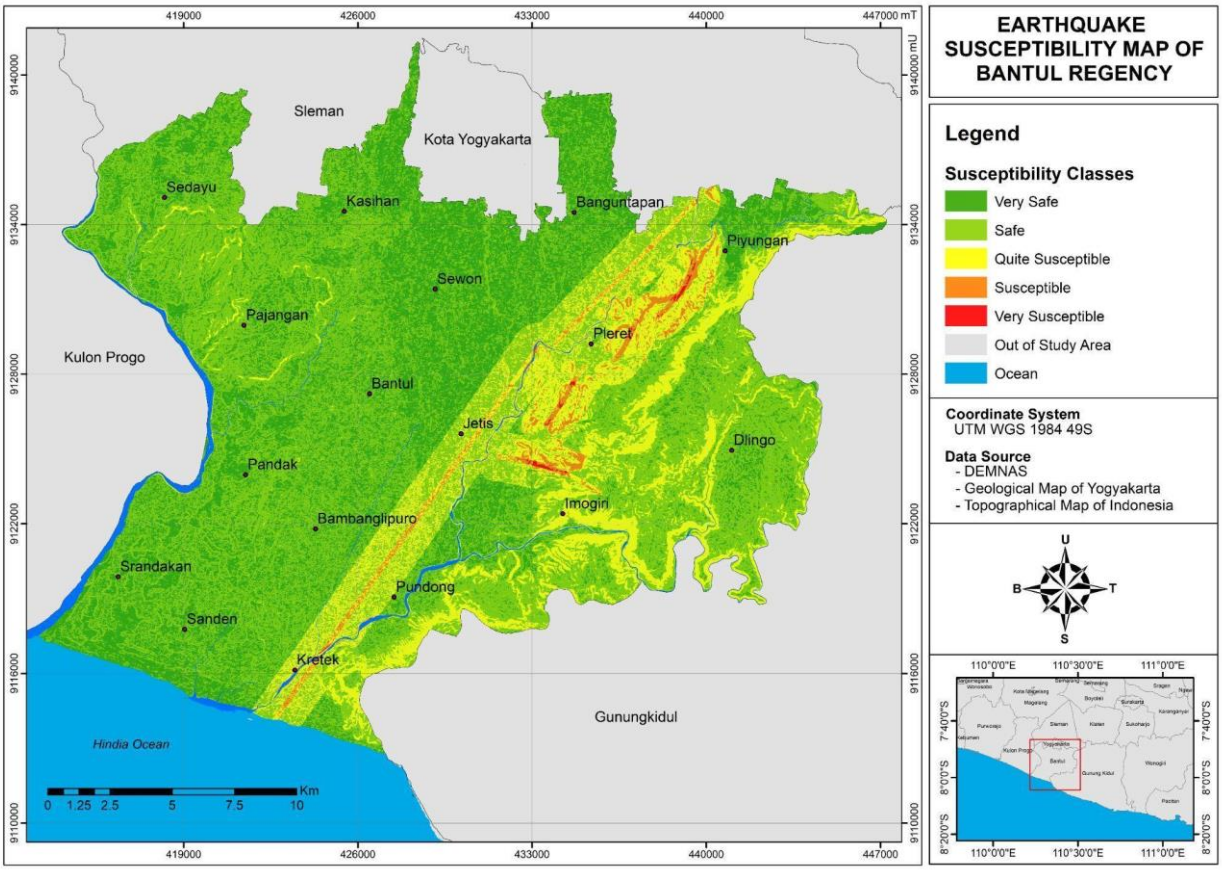

Figure 3. Earthquake Susceptibility Map of Bantul Regency

Based on existing data, it can be seen that Bantul Regency has a high susceptibility to earthquake disasters in the Opak fault area, which extends from Kretek District, Pundong District, Pleret District, and Piyungan District. Very susceptible class areas are also located around the hills in Imogiri District, Pleret District, and Piyungan District. This is because the area has a high slope. The high slope around the fault zone has the potential for severe damage when an earthquake occurs, thereby increasing the susceptibility to earthquake disasters in the area. In addition, the area around the Opak fault also has material dominated by sand, gravel, and tuff. This increases the susceptibility of earthquakes in the area because the materials are not compact and less stable when exposed to earthquakes, which can increase the damage risk to the buildings above it. Thus, it can be seen that the lower the level of earthquake susceptibility, the farther the distance from the Opak fault and the slope is also getting lower.

Tsunami Susceptibility

The tsunami hazard map of Bantul Regency has five susceptibility classes: very susceptible, susceptible, quite susceptible, safe, and very safe. In general, the southern region of Bantul Regency tends to be prone to tsunami disasters which are symbolized by the red area. Meanwhile, the northern region of Bantul Regency tends to have a classification level that tends to be safe with a green area symbol.

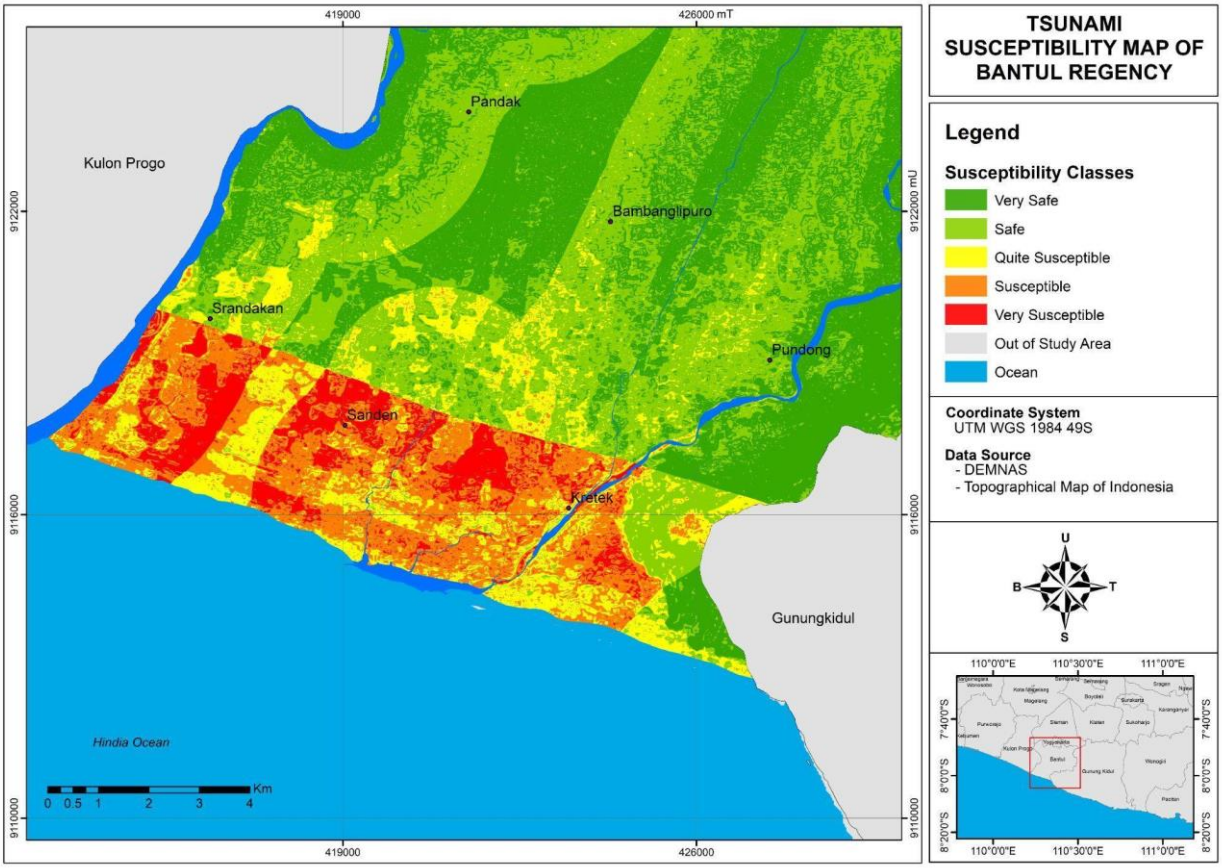

Figure 4. Tsunami Susceptibility Map of Bantul Regency

The districts with the highest level of tsunami susceptibility are Srandakan, Sanden, and Kretek districts. The districts are located in the southern part of Bantul Regency which is dominated by the susceptible classification level. This is because the Srandakan, Sanden, and Kretek districts are directly adjacent to the sea. The closer the distance to the sea and the coastline, the higher the level of tsunami susceptibility. Distance from the sea has the highest contribution to the level of tsunami susceptibility. In addition, the South Coast of Java is a tectonic area that is classified as active, so it has the potential for a tectonic earthquake that can cause a tsunami.

Another factor that contributes to the tsunami susceptibility in Bantul Regency is the height of the land and the slope of the slopes. The higher the elevation, the lower the tsunami susceptibility level. This is because the higher the terrain, the smaller the potential for a tsunami to hit, while the lower the land is, the higher the potential for a tsunami to hit. The slope of the slope affects the range of the tsunami strike, which impacts the area prone to tsunamis (Paramita et al., 2021). The gentler or lower the slope, the farther the reach and the wider the tsunami-prone area. On the other hand, the higher the slope, the safer it is from the tsunami.

Another factor that has the lowest contribution to tsunami susceptibility in Bantul Regency is the distance from the river. The closer to the river, the higher the level of tsunami susceptibility. This is because rivers can facilitate the brunt of tsunami currents because they have their own paths, so rivers can play a role as a medium for tsunami propagation. Large rivers are very influential as a medium for tsunami propagation, so their presence can increase tsunami susceptibility (Khasanah et al, 2014). Major rivers that cross Bantul Regency include the Bedog, Winongo, Opak, Oyo, Code, and Gajahwong rivers. In addition, the Progo River on the west side borders Kulon Progo Regency.

CONCLUSIONS

The susceptibility of landslides in Bantul Regency is high in hilly areas, such as in the east and northwest. Dlingo District and several areas in Imogiri District and Pleret District are areas with a predominance of landslide susceptibility class which is quite susceptible to very susceptible in the eastern area. Districts in northwestern Bantul, such as Sedayu District, Pajangan District, Kasihan District, and Pandak District tend to be susceptible from quite susceptible to susceptible class. Low landslide susceptibility classes are found in areas with low elevations and gentle slopes, such as in Banguntapan District, Sewon District, Pleret District, Jetis District, northern Kasihan District, Bambanglipuro District, western Pundong District, western Imogiri District, Srandakan District, Sanden District, and western Kretek District.

Earthquake susceptibility is influenced by slope conditions and rock material. High earthquake susceptibility in Bantul Regency occurs in several areas located on the Opak fault and hills, high susceptibility on Opak fault, namely in Kretek District, Pundong District, Pleret District, and Piyungan District. High susceptibility is also located around the hills, namely in Imogiri District, Pleret District, and Piyungan District. Low earthquake susceptibility is located in Sedayu District, Pajangan District, Kasihan District, Sewon District, Bantul District, Pandak District, Bambanglipuro District, Kretek District, and Srandakan District.

Tsunami susceptibility is influenced by the condition of the land elevation, slope, and distance from the river. The high tsunami hazard in Bantul Regency is located in the southern region of Bantul Regency, including Srandakan District, Sanden District, and Kretek District. Meanwhile, a low tsunami hazard occurred in the northern region of Bantul Regency.

Disaster susceptibility in Bantul Regency has a pattern for each disaster according to the conditions of those areas. Landslide susceptible areas are in hilly areas in the east and northwest of Bantul. Earthquake-susceptible areas are around the fault. Moreover, tsunami susceptibility is high near the coast, particularly in the southern areas of Bantul.

RECOMMENDATIONS

The results of the multi-disaster susceptibility analysis in Bantul Regency show several areas that have high disaster susceptibility. The susceptibility map can be used as a basis for determining policies related to land use in Bantul Regency so as to reduce the risk of losses due to disasters that can occur. In areas with high disaster susceptibility, efforts to increase community capacity need to be made, one of which is the establishment of disaster preparedness villages.

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