Spatial analysis of field vulnerability concerning landslide in Southern Semarang Environment

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Abstract. The study was done at Semarang, Central Java. The purpose of this study is to determine the variation of field susceptibility to landslide in the city of southern Semarang. Vulnerability includes physical, social, economic, and environmental ones. Each region has varying levels, types and characteristics of vulnerability. The results show that the vulnerability level of landslide is divided into 4 parts according to vulnerability indicator in Perka BNPB number 2 of 2012. The index categories were also modified into five categories from very low (1.00 to 1.40), low (1.41 to 1.80), moderate (1.81-2.20), high (2.21-2.40) and very high (2.41-3.0). Southern Semarang has moderate and high degree of vulnerability. The average vulnerability rate is in the high category with an index value of 2.20. The lowest average vulnerability is owned by Gunung Pati sub-District, while the highest vulnerability is owned by Candisari sub-District.

1. Introduction

The city of Semarang is an area vulnerable to disasters, and landslide is one of them. Geologically, Semarang has two topographical profiles, lowlands and high hills. Semarang lowlands is popular with downtown, whereas high hills is known as uptown. Most landslides occurs on the high hills or in the uptown since the lands are bumpy and hilly with 15-45% of slide slope.

According to BPDB data in 2014, there are 110 incidents spreading in some sub-districts. These include Gunungpati (6 incidents), Gajahmungkur (32 incidents), Southern Semarang (7 incidents), Candisari (12 incidents), Tembalang (18 incidents), Pedurungan (4 incidents), Western Semarang (12 incidents), and Ngaliyan (19 incidents). Based on that of BPDB, most landslides happened in the city of Semarang, notably in Gajahmungkur, Tembalang, and Ngaliyan sub-districts.

Disaster management in one particular area mandated in Undang-Undang No. 24 Year 2007. Hence, it is emphasized in the Regulation of Kepala Badan Nasional Penanggulangan Bencana No. 02 Year 2012 about General Guidelines for Disaster Risk Management. Therefore, Disaster Risk Management is a manifestation of government’s efforts in coordance with the formulation of activity programs and priority focus on disaster management. Diverse of disaster potential, high vulnerability level, and lack of population capacity have become awareness for some integrated plans to be effectively applied at anytime-disaster.

Disaster-prone (Threat) is a certain condition or geological, biological, climatological, geographical, social, cultural, political, economical and technological characteristics in an area for
a certain length of time. This may deflate the ability to prevent, depress, achieve readiness, furthermore, decrease the capability to cope with severe impact of numerous dangers.

Vulnerability is a condition of a community or population which lead to or cause an incapability to deal with threat or disaster. Capacity is the potential of an area and its community to take measures to reduce the levels of threat and of losses due to disaster. Disaster risk is a potential loss as a result of disaster in an area and at a certain length of time. It may result in deaths, injuries, illnesses, trauma, insecurity, refuge, damage or loss of property, and disruption of community activities. (Head of National Disaster Management Agency Regulation No.02/2012).

Vulnerability is a condition determined by factors or processes, such as physical, social, economic, and environment which decrease the ability in dealing with hazards in an area. (Indonesian Disaster Risk Index [IRBI] BNPB, 2013). Consequently, we must strive to decrease the area’s vulnerability to landslide hazards. One of ways is analysing actions in the area to decrease vulnerability toward landslide disaster based on physical, social, economic and environmental factors in order to minimize or avoid the loss of possession and casualties. Hence, increasing the ability to face landslide disaster. The objective of this research are, (1) Finding out the disparity in the level of terrain vulnerability to landslide in the city of Southern Semarang. (2) Knowing what efforts should be made to decrease vulnerability, so that disaster risk can be minimized.

2. Method

Semarang, a city in the province of Central Java is chosen as object of research. Frequent landslides causing the loss of both belongings and lives has become the consideration to this research. This study on field vulnerability toward landslide disaster is an observational research, which is quantitatively and descriptively analysed. Thus, it is picturing the condition on field with a systematical, factual, and accurate layout about facts and characteristics, also examining the correlation between the investigated phenomena. (Nazir, 2005).

The research edvariables in this study are; (1) Variable of physical vulnerability, some indicators included are houses condition, public facilities, and private/specific facilities, (2) Social vulnerability, the indicators include; (a) Number of population exposed (population density), (b) Number of vulnerable age population, toddlers (people), (c) Number of vulnerable age population, elders (people), (d) Number of female population (people), Number of handicapped population (people), and (e) trained personnels; (3) Economic vulnerability, the indicators included are; productive lands, incomes, goods-capital ownership, and assets with economic value; (4) Environment vulnerability includes some indicators; green openspace, productive forest/limited production, mixed woodlands, shrubs and water infiltration. Since each area has a variety of levels, types, and characteristics of vulnerability, data collection is conducted by some documentations, interviews, and field condition/direct surveys.

Data analysis unit exerted in this research is administration unit. Land vulnerability to landslide is analysed administratively in the levels of kelurahan (villages) and kecamatan (sub-districts). The analysis of vulnerability level in this research is based on vulnerability analysis index, consisting of loss index and exposed population index.

Thus, in order to calculate the vulnerability, we refer to a formula used by BNPB, as follow:

\[
\text{Total values of disaster vulnerability} = (0.4 \times \text{Social vulnerability Values}) + (0.25 \times \text{Physical vulnerability Values}) + (0.25 \times \text{Economic vulnerability Values}) + (0.1 \times \text{Environmental vulnerability Values})
\]

3. Results and Discussion

3.1 Research Findings

This research is conducted in Semarang, the capital city of Central Java. Geographically, it positions in between \(109^\circ 35' - 110^\circ 50'\) East Longitude and \(6^\circ 50' - 7^\circ 10'\) South Latitude. The
Semarang consists of 16 sub-districts with administrative borderlines as follow: Java Sea in the north, District of Semarang in the South, Districts of Demak and Grobogan in the East, and District of Kendal in the West.

The research areas have a maximum rainfall of 2265 mm/year. This can be seen at Kandri Station. While, Candi Rain Station states the minimum rainfall of 1483 mm/year. According to Schmidt Ferguson, the researched areas have the same type of climate, called type C (slightly wet) with Q rate (comparison between the rates of dry month with that of wet month) that is not much different.

The result shows that the level of landslide vulnerability is divided into 4 parts, in accordance to vulnerability indicators in Perka BNPB No.2 Year 2012. As mentioned before they consist of 4 values; physical, social, environment, and economic vulnerabilities. Each indicator has its own potency related to terms in Perka BNPB No.2 Year 2012, which is accordingly developed based on research needs and data availability at range.

Vulnerability index is modified into 5 categories, from the very low yaitu (1,00-1,40), low (1,41-1,80), medium (1,81-2,20), high (2,21-2,40) and very high (2,41-3,0). This grouping is a result, after calculating 4 vulnerability indicators into vulnerability index. The study presents that the city of Southern Semarang has the medium and high levels of vulnerability. The average of vulnerability level belongs to medium category with index value 2,20. The lowest vulnerability is owned by Gunungpati District, while the highest one is for Candisari District. In case of Physical vulnerability, Gajahmungkur District owns the highest values (2,89). Social vulnerability’s highest values is Candisari District (2,30). Next, for Environmental vulnerability, Candisari Districts and Western Semarang share the highest values with a very vulnerable score of 3,00. Whilst Economic vulnerability’s highest values is owned by Mijen District (2,97). The category of vulnerability index is given after calculating 4 vulnerability indicators into vulnerability index. The result is shown in the chart below.

![Figure 1](image-url)

**Figure 1.** The chart of avalanche vulnerability level per district in the city of Semarang (Source: Research 2016-2017)

Spatially, the vulnerability level in each district of Southern Semarang can be illustrated in a map below.
3.2 Distribution of Forest/Land Fires

The value of vulnerability is determined by social, physical, economic, and environment conditions of a region. Different conditions in each region result in a variety of vulnerability values. For example, the condition in a village is different from that in the city, due to its high density, complete facilities, and almost the entire areas are covered by buildings. In contrast to a village, where the population is still rare, inadequate facilities, and most areas are agricultural fields and woodlands. This condition needs to be highly considered. If that occurs in an area that is prone to landslide, it will cause different vulnerability levels toward avalanche (landslide).

Social condition, which becomes the indicator in determining the level of social vulnerability is the number of population at risk, they include women, toddlers, the elders, the disabled, and the underprivileged or low-social class. If a large number of susceptible population occupy or live in an area prone to landslide, it may lead to high social vulnerability. On the contrary, the social vulnerability will be lower if the population of susceptible people are less or not exist.

Physical condition of a region, which develops the indicator in determining physical vulnerability are housing density or the amount of houses, public services consisting of educational and worship facilities, market, and office building. Also, critical services such as hospitals, clinics, and health center units. If a large number of houses, public and critical facilities occupy a landslide-prone area, it will cause a high physical vulnerability. In other words, physical vulnerability in a region is getting higher if the area is lavish or having valuable facilities (expensive).

Economic condition of an area which becomes the indicator in determining economic vulnerability is productive lands, consisting of agricultural fields and woodlands. Also valuable assets of cattles, vehicles, and stores or kiosks, then the PDRB sector in kelurahan (village), which are all calculated based on the city’s PDRB, city area, and village area. The total amount of productive lands and valuable assets in a landslide-prone area will affect its economic vulnerability. In this area, the larger the productive lands and the higher value of valuable assets are, the higher economic vulnerability will be. In contrast, the lesser the productive lands and valuable assets in that area are, the lower economic vulnerability will be. Subsequently, the village
sector PDRB may also have an effect on the high value of vulnerability. The wider the urban areas are, the higher rupiah value of PDRB in the urban village sector will be. So that the economic vulnerability in the area that is prone to landslide, is also high.

Woodlands and shrubs are environmental conditions, which become an indicator in determining environmental vulnerability. The wider they are in the landslide-prone areas, the lower environmental vulnerability will be. On the contrary, if the woodlands and shrubs area is narrow or not existing, environmental vulnerability in landslide-prone area will be higher. The level of vulnerability of avalanche in the city of Semarang, that belongs to medium criteria are found in 5 sub-districts; Banyumanik, Gunungpati, Mijen, Ngaliyan, and Tembalang. Other 3 sub-districts, namely Candisari, Gajahmungkur, and Western Semarang belong to high criteria. The average index for the highest vulnerability value of 2.44 is Candisari sub-district, and that of lowest vulnerability value of 2.03 is Gunungpati.

Having been affected by the mean value of physical and environmental vulnerabilities, Candisari sub-district has average index of the highest vulnerability. There are 5 villages in Candisari sub-district owning values of 3.00 for physical vulnerability, causing them to have the rate of 2.87, which is quite high for the average (mean) value of physical vulnerability. The value for environmental vulnerability in all villages of the same sub-district is 3.00. This too, has made the average value of environmental vulnerability high (3.00).

Judging from the loss value of physical vulnerability, Candisari subdistrict’s loss is Rp 482.370 (juta), this consists of the amount of loss value from houses for Rp 290.620 (millions), public facilities for Rp 150.250 (millions) and critical facilities for Rp 41.500 (millions). Meanwhile, the excessive value of environmental vulnerability is due to the lack of forest. The existing plantation is only a few of relatively narrow woodlands, for 30,02 ha and shrub for 0,53 ha. These have made the sub-district vulnerable to landslide disaster.

The average of the lowest vulnerability index (2.03) is in Gunungpati sub-district. The low vulnerability index in this district is influenced by the value of social vulnerability, and low environmental vulnerability. It is knowledgeable that the whole villages in Gunungpati district have the low values of social vulnerability, that the average is only 1.23. The same case as the environmental vulnerability values, of which the average is low for the entire villages, merely 1.65.

Population density and the condition of exposed population, such as women, susceptible population (infants and senior citizens), the underprivileged, disabled people. Although the numbers are few, they can be the cause of low social vulnerability in the sub-district. Another cause of lower environmental vulnerability in Gunungpati is its 2.972,99 ha mixed woodlands of, of all villages this belongs to low score (1.00). However, the sub-district has a high score for shrubs (3.00) in all villages. The area of shrubs/bushes itself covers 370,62 ha. Despite all that, Gunungpati sub-district is categorized into low environmental vulnerability, since mixed woodlands have higher points (60) than shrubs (40), which means the shrubs is slightly affecting environmental vulnerability to landslide disaster.

Based on the result of the data analysis on area vulnerability to landslides, the explanation is that, the avalanche vulnerability level in the Sub-districts of Banyumanik, Gunungpati, Mijen, Ngaliyan, and Tembalang is included in the medium criteria. While the avalanche vulnerability level of Sub-districts Candisari, Gajahmungkur, and Western Semarang is included in the high criteria.

There are several efforts that can be prepared and organized in order to decrease the vulnerability concerning landslide disaster, and minimize the risk. They are: (1) Visibly administering (restricting) by regulation the use of lands or areas potential to landslide, (2) Requiring the community to construct strong bulding foundation, yet light for upper part to minimize the risk of landslide, (3) Structuring community organisation of which function is to protect and save the susceptible ones (elders, pregnant women, disabled) from landslide, (4) Community, together with government need to organize new public facilities in landslide-prone areas, (5) Attempting to empower variety of assets and human resources in landslide-prone areas, (6) Relocating disaster-prone settlements to a safer place, (7) There needs to be a village apparatus or community organisation (youth association) that specifically handles landslide disaster

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management, (8) A need for landslide disaster evacuation and First Aid trainings to each group of susceptible community, (9) Availability of surveilant posts in landslide-prone zones.

4. Conclusion
In reference to the result of this research and discussion, it can be concluded that: (1) The condition of the field vulnerability level towards landslides varies in 2 categories, namely medium level to high; (2) The average of vulnerability level belongs to medium category. The lowest vulnerability is owned by Gunungpati District. The highest one is for Candiisari District. In case of Physical vulnerability, Gajahmungkur District owns the highest values. Social vulnerability’s highest values is Candiisari District. Next, for Environmental vulnerability, Candiisari Districts. Whilst Economic vulnerability’s highest values is owned by Mijen District; (3) The value of vulnerability is determined by social, physical, economic, and environment conditions of a region. Different conditions in each region result in a variety of vulnerability values; (4) several efforts that can be prepared and organized in order to decrease the vulnerability concerning landslide disaster, they are: (a) Visibly administering (restricting) by regulation the use of lands or areas potential to landslide, (b) Requiring the community to construct strong bulding foundation, yet light for upper part to minimize the risk of landslide, (c) Structuring community organisation of which function is to protect and save the susceptible ones (elders, pregnant women, disabled) from landslide, (d) Community, together with government need to organize new public facilities in landslide-prone areas, (e) Attempting to empower variety of assets and human resources in landslide-prone areas, (f) Relocating disaster-prone settlements to a safer place, (g) There needs to be a village apparatus or community organisation (youth association) that specifically handles landslide disaster management, (h) A need for landslide disaster evacuation and First Aid trainings to each group of susceptible community, (i) Availability of surveilant posts in landslide-prone zones.

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