Risk analysis of landslide as a basis of mitigation plan: a case study of Mangunan Village, Bantul, Indonesia

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Abstract. When rainy season comes, in Mangunan Village, landslide occurs frequently. Mangunan is one of the villages in Bantul District that possesses high intensity of landslide events. Located in a contoured hilly area on the eastern region of Bantul District is one of the reasons. This study aims to analyze the risk of landslide in Mangunan by detailing the risk map, which constitutes a general risk map, and to identify the number of households that are currently residing in each risk-zone area. In this study, we applied a descriptive method that combined both qualitative and quantitative approaches in order to generate a good depiction of settlements in each risk-zone area. The data of this study can be classified into two categories, primary and secondary data. Primary data were obtained from field activities such as interviews and field documentation. Meanwhile, secondary data were obtained from archives, notes, or reports from related agencies. The results of this study are: 1) the number of settlements that are located in high- and medium-vulnerability areas are 143 and 12, respectively; 2) Mangunan Village possesses high hazard level, medium to high vulnerability level, and high-capacity level which means the village has medium to high risk level; 3) Recommendations of infrastructure development for landslide mitigation.

1. Introduction
Landslides affect structures built by human beings whether they are directly on or near a landslide. Residential dwellings built on unstable slopes may experience damage, including partial to complete destruction as landslides destabilize or destroy foundations, walls, and utilities [1]. This one of the threats found in Bantul. Of 75 villages in Bantul, there are 16 that are categorized as landslide-prone villages. One of them is Mangunan Village. The vast majority of the areas of Bantul possesses a risk of landslide event. According to Aminatun [2], this condition is caused by the geographical location of Bantul which is located in a contoured hilly (slope) area. This type of area mostly can be found on the east side and partly on the west side of the district (see Figure 1). Broadly, the southern mountain region stratigraphy can be classified in two kinds of sequences, namely western and southern and southeastern stratigraphy.

The map of slopes of Bantul District as shown in Figure 1 consists of several colors. Each color represents different slope inclination. The dark red color represents the areas with extreme inclination of slopes. The brown color represents the areas with steep slopes. The red color represents the areas with
slightly steep slopes. The yellow color represents the areas with less steep slopes. The green color represents flat areas.

Today, the international framework of disaster management refers to Sendai Framework for Disaster Risk Reduction 2015-2030 [4]. Sendai Framework is the successor of Hyogo Framework for Action that previously became the reference of disaster risk reduction framework from 2005 to 2015. In Sendai Framework, there are several key priorities: 1) Understanding the risk of disaster; 2) Strengthening disaster risk governance to manage the risk of disaster; 3) Investing in disaster risk reduction for resilience; 4) Enhancing disaster preparedness for effective response, and to "Build Back Better" in recovery, rehabilitation and reconstruction. As an effort to reduce the risk of disaster, as mentioned in the 2015-2030 Sendai Framework for Disaster Risk Reduction [4,5], a risk analysis study of an area is needed. It is a first step in developing a disaster management strategy in the future. Based on the considerations above, as one of the efforts to reduce the risk of landslides in Bantul district as seen in Figure 1, a detailed disaster risk analysis study is needed.

This study aims to analyze the risk of landslide in Mangunan Village. The steps are 1) detailing the disaster risk map, which constitutes a global risk map; 2) finding out the number of houses (household) in each disaster risk zone (red, yellow, green) and; 3) assessing the values of each risk parameter to determine the risk value of landslides. Ultimately, as a follow up to the risk analysis, a disaster risk reduction program will be developed.

Figure 1. The Map of Slopes of Bantul District [6].
2. Literature Reviews

2.1. Previous Studies
In Indonesia, the guideline for risk analysis of disaster is regulated in The Regulation of The Head of National Disaster Management Agency (PERKA BNPB) Number 2 Year 2012 [7]. Disaster risk analysis is an approach effort to depict the negative risk that may appear subjected to the occurrence of particular hazard events. The risk is estimated based on vulnerability and capacity of the assessed areas such as potential fatalities or casualties, loss of properties, loss of economic, and loss of environment.

In this research, some parameters of risk analysis of landslide are compiled from several previous studies, such as:
1. The research of Hasan [8] from Department of Disaster Management, Graduate Program, Faculty of Engineering, Universitas Gadjah Mada. The title of the research is Evaluation of Rock Avalanches Risk in Kelir Sub-village, Girimulyo Sub-district, Kulonprogo District.
2. The research from Haryanto [9] from Department of Disaster Management, Graduate Program, Faculty of Engineering, Universitas Gadjah Mada. The title of the research is Landslide Risk Assessment in Semarang City Central Java Province.
3. The research of The Regional Planning Agency (BAPPEDA) Yogyakarta Special Region in 2008 [10]. The title is The method of Disaster Risk Mapping of Yogyakarta Special Region. The outcome of the research was a disaster risk map of Yogyakarta Special Region.
4. The research of The Center of Disaster Study UPN Veteran Yogyakarta [11]. The topic is disaster risk mapping.

The research mentioned above encompassed multiple hazards and some were in a global scale. Therefore, in this research, some adjustments are needed in order to keep the focus on landslide events.

2.2. Disaster Risk Analysis
As written in PERKA BNPB No. 02 Yr. 2012, in order to analyze the risk of disasters, there are, at least, three parameters that should be taken into account, namely Hazard, Vulnerability, and Capacity. These three parameters can be written in a simple formula as follows:

\[ Risk = \text{Hazard} \times \frac{\text{Vulnerability}}{\text{Capacity}} \]  

Formula (1) shows the relationship between those three parameters of risk. In short, it can be understood that the higher the value / weight of Hazard and Vulnerability, the higher the value of Risk. But on the contrary, the higher the Capacity value, the smaller the value / risk of Risk. By understanding the relationships between these components, efforts can then be prepared to reduce the risk by:
1. Reducing/lessening Hazard
2. Reducing/lessening Vulnerability
3. Improving/scaling up Capacity

In disaster risk analysis, the involvement of the community and policy makers is essential since the community and stakeholders are the subject and also the object of the study. Therefore, with the implementation of this participatory method or communities and stakeholders engagement, disaster risk analysis can be a holistic study as a form of shared learning.

2.3. Disaster Risk Map
A risk map is the merger result of hazard maps, vulnerability maps, and capacity maps. Each of these maps is obtained from various indices analyzed from the various data and methods. In brief, the flowchart of risk map preparation can be seen in Figure 2.
2.4. Weighting of Hazard
In this study, weighting of hazard parameters was carried out based on PERKA BNPB No.2 Year 2012 concerning General Guidelines for Disaster Risk Analysis. Further weighting of hazard parameters is presented in Table 1.

Table 1. Weighting of Landslide Hazard Parameters.

| No | Parameters                  | Weight | Max. Score | Min. Score |
|----|-----------------------------|--------|------------|------------|
| 1  | Soil Texture Class          | 1      | 3          | 1          |
| 2  | Soil Solum Thickness        | 1      | 3          | 1          |
| 3  | Level of Rocks Weathering   | 1      | 3          | 1          |
| 4  | Slope Inclination           | 5      | 15         | 5          |
| 5  | Types of Morphology         | 3      | 9          | 3          |
| 6  | History of landslides       | 1      | 3          | 1          |
| 7  | Vegetation Density          | 1      | 3          | 1          |
| 8  | Land use                    | 1      | 3          | 1          |
| 9  | Rainfall Data               | 1      | 3          | 1          |
|    | Total                       | 15     | 45         | 15         |
Weighted Method was carried to give weight to the parameters of landslide. It is calculating maximum score subtracted by maximum score of weighting. The subtraction result is then divided into 3 classes which represents three classes of hazard.

\[
\text{Interval} = \frac{\text{Max. Score} - \text{Min. Score}}{3}
\]

\[
\text{Interval} = \frac{45 - 15}{3} = 10
\]

Based on those scorings, the classes of hazard can be classified as shown in Table 2.

| Score Interval | Criteria | Classes |
|----------------|----------|---------|
| 15 -24         | Low      | Green   |
| 25 – 34        | Medium   | Yellow  |
| 35 – 45        | High     | Red     |

2.5. **Weighting of Capacity Parameters**

Weighting the capacity parameter refers to PERKA BNPB No. 02 of 2012 concerning General Guidelines for Disaster Risk Analysis. Further weighting of the capacity parameters is presented in Table 3.

| No. | Assessed Elements               | Weight | Max. Score | Min. Score |
|-----|---------------------------------|--------|------------|------------|
| 1.  | Number of Hospitals, Puskesmas, Polindes | 1      | 3          | 1          |
| 2.  | Number of Schools               | 1      | 3          | 1          |
| 3.  | Number of Medical Officers      | 1      | 3          | 1          |
| 4.  | DRR Agency                      | 1      | 3          | 1          |
| 5.  | Evacuation Line markings        | 1      | 3          | 1          |
| 6.  | Early Warning System            | 1      | 3          | 1          |
|     | Total                           | 6      | 18         | 6          |

By applying weighted method, we can calculate the interval score of risk criteria. The calculations are as follows:

\[
\text{Interval} = \frac{\text{Max. Score} - \text{Min. Score}}{3}
\]

\[
\text{Interval} = \frac{18 - 6}{3} = 4
\]

Based on those scorings, the classes of capacity can be classified as shown in Table 4.

| Score Interval | Criteria | Classes |
|----------------|----------|---------|
| 6 – 10         | Low      | Green   |
| 11- 14         | Medium   | Yellow  |
| 15 – 18        | High     | Red     |

2.6. **Weighting of Disaster Risk**

Weighting of disaster risk parameters refers to PERKA BNPB No. 02 Year 2012 concerning General Guidelines for Disaster Risk Analysis. Further weighting of the disaster risk parameters is presented in Table 5.
Table 5. Weighting of Landslide Disaster Risk.

| No | Assessed Elements | Max. Score | Min. Score | Percentage | Final Max. Score | Final Min. Score |
|----|-------------------|------------|------------|------------|-----------------|-----------------|
| 1. | Hazard            | 45         | 15         | 0.5        | 22.5            | 7.5             |
| 2. | Vulnerability     | 25         | 9          | 0.3        | 7.5             | 2.7             |
| 3. | Capacity          | 15         | 6          | 0.2        | 3.6             | 1.2             |
|    | Total             | 88         | 30         | 6          | 33.6            | 11.4            |

By applying weighted method, we can calculate the interval score of risk criteria. The calculations are as follows:

Interval = (Max. Score - Min. Score)/3
Interval = (33.6 - 11.4)/3 = 7.4

Based on those scorings, the classes of capacity can be classified as shown in Table 6.

Table 6. The Weighting Interval of Disaster Risk.

| Score Interval | Criteria | Classes |
|----------------|----------|---------|
| 26.3 – 33.6    | Low      | Green   |
| 18.9 – 26.2    | Medium   | Yellow  |
| 11.4 – 18.8    | High     | Red     |

2.7. Geographic Information System (GIS)
Geographic Information System (GIS) consists of a set of components that cannot be separated from one another. These components are as follows:

- Brainware (Human being)
- Data (analog maps, survey data, statistics, aerial photographs, previous GIS data, etc.)
- Hardware (computer, scanner, digitizer, etc.)
- Software (ArcGis, Map Info, Surfer, Autocad, etc.)

In this research, we used ArcGis, Version 9.3. This software is used to calculate the slope percentage, and calculate and evaluate which units, classes or types of each individual map are important (influential) on the occurrence of ground movements.

Based on Decree of the Minister of Energy and Mineral Resources No.1452/K/10/MEM/2000 concerning Technical Guidelines for Mapping the Zone of Vulnerability in Land Movements, mapping of land vulnerability zones can be carried out by direct mapping, indirect mapping and combined methods.

In addition to using the GIS method, the approach of this research is also a quantitative method (statistical method). This method is based on the calculation of ground motion density and weight value of each unit, class or type on each parameter map. The method of calculation based on the calculation of the area of motion of the land. The density value of each unit, class or type on each parameter map is a reflection of the extent of the occurrence of ground motion in one unit (unit, class or type) per area of the unit area, class or parameter type.

3. Materials and Methods
The research methodology consists of data collection and data analysis. In this study, data collection and data analysis refer to research conducted by Aminatun and Muntafi [3].
3.1. Data Collection
In this study, data collection was carried out through several stages, namely observation, interviews and Focus Group Discussion (FGD), secondary data collection, and direct assessment. Explanation of each stage is as follows:
1. Observation was conducted by observing and measuring directly at the research location.
2. Interviews and FGDs were conducted through direct discussions with key informants consisting of local residents, community leaders, women and youth leaders, related officials at the village, sub-district and district levels.
3. Secondary data collection was carried out by collecting documents needed for study material, including study documents that have been prepared previously.
4. The assessment was carried out by filling out a questionnaire form which includes the parameters that have been determined.

3.2. Data Analysis
Data analysis was conducted in the following steps.
1. Inventorying and classifying data that has been obtained for each parameter.
2. Determining the level and magnitude of the indicators that have been obtained.
3. The level and magnitude of the indicators that have been grouped are then tabulated.
4. Each location that has been labeled then the level of vulnerability of each location point is determined.
5. Analyzing threat analysis, vulnerability, and community capacity as well as
6. Analyzing the risk of landslide in assessed areas
7. Mapping based on previous analysis results and supported by geological map, slope inclination map, rainfall map, and land use map.
8. Utilizing ArcGIS to overlay maps to create hazard map and risk map of landslide
9. Bringing the map to Focus Group Discussion (FGD) to obtain comments and suggestions and improve the map
10. The final map is then socialized in a workshop.

4. Results and Discussion
4.1. Weighting of Hazard
Based on the parameters that have been compiled previously, each of these parameters is assigned with a weighting score according to the magnitude of the effect of these parameters in assessed areas. The weighting of the parameters is presented in Table 7.

Table 7. The Weighting of Hazard Parameters of Mangunan Village Subjected to Landslide.

| No | Parameters                  | Weight | Score | Total |
|----|-----------------------------|--------|-------|-------|
| 1  | Soil Texture Class          | 1      | 3     | 3     |
| 2  | Soil Solum Thickness        | 1      | 3     | 3     |
| 3  | Level of Rocks Weathering   | 1      | 3     | 3     |
| 4  | Slope Inclination           | 5      | 3     | 15    |
| 5  | Types of Morphology         | 3      | 3     | 9     |
| 6  | History of landslides       | 1      | 3     | 3     |
| 7  | Vegetation Density          | 1      | 3     | 3     |
| 8  | Land use                    | 1      | 3     | 3     |
| 9  | Rainfall Data               | 1      | 2     | 2     |
|    | **Total**                   |        |       | **44**|
The score of the assessment of the hazard parameters of the landslide is 44. In other words, the Mangunan Village had high threat criteria so that it was included in the red zone.

4.2. Vulnerability

Vulnerability is a condition of a community or community that leads to or causes inability to face disaster threats or biological, economic, social, cultural, political conditions / characteristics, culture, physical and technology of a society in a region that reduces the community to prevent, reduce, achieve readiness and respond to the effects of certain hazards [3]. Components of vulnerability used in this method include physical, demographic, economic and environmental components. Weighting of vulnerability parameters is shown in Table 8.

| No | Assessed Elements                                | Weight | Score | Total |
|----|-------------------------------------------------|--------|-------|-------|
| 1. | Number of households in one house               | 1      | 2     | 2     |
| 2. | Number of family members in one house           | 1      | 3     | 3     |
| 3. | Home ownership Status                           | 1      | 3     | 3     |
| 4. | Land ownership status                           | 1      | 2     | 2     |
| 5. | Land Area                                       | 1      | 3     | 3     |
| 6. | Type of building                                | 3      | 2     | 6     |
| 7. | Other land uses                                 | 1      | 3     | 3     |
|    | **Total**                                       |        |       | **22**|

The score of the assessment of the vulnerability parameters of the landslide is 22. In other words, Mangunan Village is included in the red zone, which constitutes high vulnerability.

4.3. Capacity

Aminatun and Muntafi [3] define capacity resources as resources, ways and strengths owned by the community that enable the community to maintain and prepare themselves, prevent, respond, reduce and quickly recover from the consequences of disasters. Community capacity can be in the form of physical and non-physical (social) components. The physical and non-physical (social) components are measured based on the village area because the smallest spatial administrative data is the village. Weighting is shown in Table 11.

| No | Assessed Elements                                      | Weight | Score | Total |
|----|-------------------------------------------------------|--------|-------|-------|
| 1. | Number of Hospitals, *Puskesmas, Polindes*             | 1      | 3     | 3     |
| 2. | Number of Schools                                     | 1      | 2     | 2     |
| 3. | Number of Medical Officers                            | 1      | 2     | 2     |
| 4. | DRR Agency                                            | 1      | 2     | 2     |
| 5. | Evacuation Line markings                              | 1      | 3     | 3     |
| 6. | Early Warning System                                  | 1      | 3     | 3     |
|    | **Total**                                             |        |       | **15**|

The score of the assessment of the capacity parameters of the landslide is 15. This means that Mangunan Village has a medium capacity represented by yellow color.
4.4. Risk Analysis

Landslide risk analysis is a combination of 3 main components, namely threats (H), Vulnerability (V) and capacity (C). Each total weight of threats, vulnerabilities and capacities for this risk will have different values. From the weighting of the maximum and minimum values of each threat, vulnerability and capacity summed then the percentage of each weighting is taken to the total weighting number. The percentage obtained is then multiplied by the maximum and minimum values of the specified criteria. The results of the landslide risk analysis are presented in Table 10. Whereas the result of the mapping based on the landslide risk zone in Mangunan Village is shown in Figure 3.

Table 10. The Weighting of Risk of Mangunan Village Subjected to Landslide.

| Parameters | Zone  | Cempluk | Kanigoro | Kediwungg | Lemat Abang | Mangunam | Sukorame | Total |
|------------|-------|---------|----------|-----------|-------------|----------|----------|-------|
| Hazard     | Red Zone | 0       | 2        | 4         | 0           | 0        | 3        | 9     |
|            | Yellow Zone | 3       | 28       | 29        | 10          | 12       | 13       | 95    |
|            | Green Zone | 21      | 1        | 6         | 5           | 8        | 10       | 51    |
| Vulnerability | Red Zone | 24      | 31       | 39        | 6           | 20       | 23       | 143   |
|            | Yellow Zone | 0       | 0        | 0         | 9           | 0        | 3        | 12    |
|            | Green Zone | 0       | 0        | 0         | 0           | 0        | 0        | 0     |
| Capacity   | Red Zone | 0       | 0        | 0         | 3           | 1        | 0        | 4     |
|            | Yellow Zone | 14      | 7        | 3         | 3           | 7        | 11       | 45    |
|            | Green Zone | 0       | 0        | 2         | 0           | 0        | 2        | 4     |
|            | Red Zone | 22      | 3        | 39        | 4           | 20       | 15       | 103   |
| Risk       | Yellow Zone | 2       | 28       | 0         | 11          | 0        | 11       | 52    |
|            | Green Zone | 0       | 0        | 0         | 0           | 0        | 0        | 0     |
Figure 3 shows the vast majority of Mangunan Village areas have landslide risk level from medium to high (yellow to red).

4.5. Development program recommendations
The results of the landslide risk analysis of Mangunan Village, Imogiri Sub-district, Bantul Regency are shown in Table 12. Next, in the context of landslide risk reduction, it is necessary to develop the related infrastructure in the area based on the level of risk of the disaster.

1. High Risk
In high-risk areas, disaster risk reduction option is relocation which means moving people from high-risk areas to safer places. The relocation areas should meet some requirements, such as a) houses should apply earthquake resistant concept, b) evacuation routes should have to lanes so that four-wheeled vehicles can walk past each other, c) drainage systems work well, and worship places are available.
2. Moderate Risk
   In these areas, some infrastructures need to be constructed, such as retaining wall, drainage channels, and evacuation routes

5. Conclusion
The conclusions of this study are:
1. 103 households are located in Red Zone, 52 households are located in Yellow Zone, and no households is located in Green Zone.
2. Mangunan Village has moderate to high threat values, moderate to high vulnerability, and low to moderate capacity, so the risk value is moderate to high.
3. To reduce the risk of landslide in Mangunan Village, improvement of capacity such as enhancement of physical (infrastructure) and non-physical mitigation is essential including:
   - For high-risk areas, relocation to safer places is a highly recommended option. Construction of houses in relocation areas should apply the concept of earthquake resistant buildings.
   - For moderate-risk areas, a retaining wall, drainage canal and tree planting are recommended suggestions.

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