Disaster Risk Analysis of Merapi Volcano Eruption in Cangkringan District Sleman Regency

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Abstrak. Cangkringan is located in the Merapi Volcano Disaster Prone Areas which has the potential to be affected by eruption. The eruption of Merapi Volcano is a consequence that must be faced by the local resident, so that the need for disaster risk analysis in the region through research is a must. This disaster risk analysis research aims to (1) Analyze the risk level of Merapi Volcano eruption in Cangkringan. (2) Analyze the risk distribution of Merapi Volcano eruption in Cangkringan. This research is a descriptive research with a quantitative approach conducted in Cangkringan District, Sleman Regency, Special Region of Yogyakarta. The population in this study is the entire village in Cangkringan. The entire area is the subject of this research. The variables of this research are hazard, vulnerability and capacity. This study used primary data and secondary data. Data collection techniques used are observation, interviews, and documentation. Data analysis techniques used are scoring, overlay and descriptive. The results of this study indicate: (1) The level of risk of Merapi Volcano Eruption in Cangkringan is divided into four levels which are high, medium, low and very low. The area of Cangkringan has a high level of risk covering an area of 19.00% of the total area, the medium-risk level is 38.38% of the total area, the low-risk level is 16.61% of the total area, the very low-risk level is 20.23% of the total area of Cangkringan District. The higher the level of disaster risk, the greater the potential loss due to the eruption of Merapi Volcano. (2) The distribution of disaster risk of Merapi Volcano Eruption in Cangkringan is in the entire village. The distribution of high-risk level is in part of Umbulharjo Village, part of Glagaharjo Village and part of Argomulyo Village. The distribution of medium-risk level is in part of Umbulharjo Village, part of Kepuharjo Village and part of Glagaharjo Village. The distribution of low-risk level is in part of Kepuharjo Village, part of Wukirsari Village and part of Argomulyo Village. The distribution of very low-risk level is in part of Wukirsari Village and part of Argomulyo Village.

1. Introduction

Indonesia is a country located between three active plates in the world which are the Eurasian Plate, the Indo-Australian Plate, and the Pacific Plate. The three plates collided with each other and caused an active subduction zone in Indonesian territory. The existence of this active subduction movement causes volcanic activity in Indonesian territory.

One of the active volcanoes in Indonesia is Mount Merapi. Merapi Volcano is located in two provinces which are Special Region of Yogyakarta and Central Java, and four districts including Sleman Regency, Magelang Regency, Klaten Regency and Boyolali Regency. Merapi Volcano is a Strato-type volcano with a height of 2,965 meters dpl. Volcanoes have two characteristics, on the one hand, volcanoes can provide the availability of natural resources, especially fertile land, so that it can be used by local resident who live around Merapi Volcano. The existence of these fertile land conditions makes the population on the slopes of Mount Merapi on average work in the agricultural sector, besides that mineral C is also abundant [3].
The activity of Merapi Volcano tends to be high in eruptive activity. Since 1006, Merapi Volcano continues to experience eruptions regularly with a span of one to seven years and until has recorded eruptions of more than 80 times until now. On this basis, Mount Merapi is often referred to as a never sleeps volcano [1], but currently the volcanic activity of Mount Merapi is slightly different from before. Since the 2010 eruption, it has been counted more than seven years that Merapi Volcano has not yet experienced an eruption again. This indicates that a greater magnitude of potential eruptions is likely to occur and of course the magnitude of the risk is also greater. The last explosive eruption of Merapi Volcano occurred in 2010 and caused enormous damage and disaster.

The area of Cangkringan District is one of the areas affected by the eruption of Mount Merapi in 2010. In the eruption that occurred in 2010, precisely in October to November 2010, the direction of the eruption, especially the eruption material in the form of hot clouds, was issued several times to the west, southwest, south and southeast [4]. The location of Cangkringan District, which is on the southeast side of Merapi Volcano, is certainly affected by the eruption material that was generated when the eruption occurred. The Center for Volcanology and Geological Hazard Mitigation (CVGHM) showed that the Cangkringan District area is in a Disaster Prone Area where it has the potential to be affected by eruptions.

The eruption of Merapi Volcano on October 26, 2010 until it reached the peak of the biggest eruption on November 5, 2010 caused considerable damage and loss. Sleman Regency is the area most affected by the disaster where it is estimated that around 65% of the damage and losses [2]. Based on the data compiled by the Sleman Regency Government, there are 2,271 houses in the Cangkringan District suffered damage due to the eruption of Merapi Volcano.

| Table 1. Data of Damaged Houses in Cangkringan District |
|---------------------------------|
| Data on Damaged Houses Due to the Eruption of Mount Merapi |
| 26 October – 5 November 2010 |

| No. | District | Village | Total | Damaged | Percent (%) |
|-----|---------|---------|-------|---------|-------------|
| 1.  | Cangkringan | Glagaharjo | 855   | 625     | 73          |
| 2.  | Argomulyo | 862     | 297   |         | 34          |
| 3.  | Kepuharjo | 802     | 736   |         | 91          |
| 4.  | Wukirsari | 531     | 268   |         | 50          |
| 5.  | Umbulharjo | 345    | 345   |         | 100         |
|     | **Total** | 3385   | 2271  |         | 348         |

Source: Sleman Regency Government Data, 2010

In addition to causing physical damage, the 2010 Merapi Volcano eruption also caused casualties. Based on the data from the Sleman Regency Health Office compiled by the Sleman District Health Office in 2010, the number of victims who died as a result of the 2010 Merapi eruption was 277 people on December 2, 2010. Most of the victims came from the Cangkringan District area.

Cangkringan District is on the southeast side of Mount Merapi which consists of 5 villages namely Wukirsari, Argomulyo, Glagaharjo, Kepuharjo and Umbulharjo. According to the data from the Central Bureau of Statistics in Sleman Regency 2017, the population in this district is 29,456 people in 2017, with a population density of 617 people per km2. Cangkringan District has abundant natural resources and also supported by fertile land. The land in this area is 47.99 km2 with various agricultural commodities in it. Therefore, people in this area are reluctant to leave this area. They still do some activities and lives in this area, even though this area is in Disaster Prone Area of Merapi Volcano.

Community activities in the Disaster Prone Area of Merapi Volcano have the potential to be exposed to primary and secondary hazards that can threaten human life, property and livelihoods there. From the conditions in the field, it is necessary to make efforts to identify and reduce the risk posed by the hazard of Merapi Volcano in the Cangkringan District by the disaster management agency and community.

Disaster management measures must require a strong basis in their implementation. Therefore, the need of a disaster risk assessment in the form of a tool is important to assess the possible magnitude of losses due to existing threats. By knowing the possible risk of a disaster that occurs, it can minimize the impact and loss that can occur someday. Based on the observations that have been made, Cangkringan
District area has not been maximized in disseminating information about the level and the distribution of the disaster risk of Merapi Volcano eruption in the Cangkringan District. Because of the condition of Cangkringan District that has not been maximal in disseminating information about the level and the distribution of the disaster risk of eruption in the region, this research is carried out with the aim of analyzing the risk level of Merapi Volcano eruption and analyzing the risk distribution of Merapi Volcano eruption in Cangkringan District.

2. Theoretical Framework
Cangkringan District is located in the Merapi Volcano Disaster Prone Areas. In this way, it causes catastrophic disasters due to the eruption of Merapi Volcano. Disaster analysis is needed to measure the potential loss of both properties and casualties of volcanic eruption. The disaster analysis not only considers the level of hazard from volcanic eruptions, but also considers the level of vulnerability and capacity in the area.

The hazard level of Merapi Volcano eruption in Cangkringan District is affected by the location of the area towards Mount Merapi. Based on the Map of Merapi Volcano Disaster Prone Areas published by the Geological Agency, the level of hazard due to the eruption of Merapi Volcano is divided into KRB I, KRB II, and KRB III. The level of vulnerability is influenced by several variables, such as physical vulnerability using the parameter of buildings vulnerability (houses and public facilities), economic vulnerability using the parameter of productive land area (rice fields, moor, ponds and plantations) and Gross Regional Domestic Product (GRDP), environmental vulnerability using the parameter of land use (protected forest, plantations, shrubs, rice fields / moor and settlements) and social vulnerability using the parameter of population density and the ratio of vulnerable groups (ratio of age group, ratio of sex, ratio of disabled people and ratio of poverty). The level of capacity in the volcanic eruption disasters is influenced by five variables including the existence of an early warning system, the reduction of basic risk factors, the existence of disaster management organizations, the presence and type of disaster socialization, and the presence and type of disaster mitigation.

In this research, the disaster risk analysis used scoring and map overlay methods. The scoring method is done by giving a score to each of the hazard, vulnerability and capacity variables. The overlay method is done by overlaying all the variables of hazards, vulnerabilities and capacities that have been changed in the form of maps and which have been marked for each disaster in the study area. After scoring and overlaying all relevant variables, the distribution and level of risk in volcanic eruption disaster will be shown on a map. Later, the map of the risk level of Merapi Volcano eruption can be used by the residents and the government agencies in Cangkringan District as a guide for carrying out disaster management in Cangkringan District.

3. Research Methods
This research is based on the method and problem discussion and it is a descriptive research. This research will describe everything in the field, especially the risk of disaster that may occur when the eruption of Merapi Volcano occurs again in the Cangkringan District area. This study uses a quantitative approach as one of the supporting methods during the research activities. The data from the results of this study will be presented in the form of a frequency table for further scoring. The scoring result data is then used as a guide in the analysis of map overlay.

This research was conducted in Cangkringan District, Sleman Regency. The determination of the location of this research is based on the Map of the Volcano Hazard Prone Areas of Merapi. This research was conducted from October 2019 to March 2020. The population in this study was the entire area of Cangkringan District which consists of five villages namely Umbulharjo Village, Kepuharjo Village, Glagaharjo Village, Argomulyo Village, and Wukirsari Village. This research is a population study so that the entire area is the subject of the research.

Data collection methods in this study are observation, interviews, and documentation. The data analysis techniques used in this study were scoring analysis, map overlay analysis in geographic information systems, and descriptive analysis.

4. Result & Discussion
4.1 The Description of the Research Area
Cangkringan District is located in the northern part of Sleman Regency. Astronomically, Cangkringan District is located between 434000-444000mT and 9152000-9162000 mU, Cangkringan District has an area of 4,799 hectares (47.99 km2) with a population of 29,592 people, consisting of 14,673 male residents and 14,919 female residents. Cangkringan District has a population density of 617 people / km². Cangkringan District is divided into five villages including Wukirsari, Argomulyo, Glagaharjo, Kepuharjo and Umbulharjo. The following bellow is an area division of each village or sub-district in Cangkringan District.

| No. | Village  | Total (Soul) | Large (Km²) | Population Density Level (Soul/Km²) |
|-----|----------|--------------|-------------|------------------------------------|
| 1.  | Wukirsari| 10.291       | 14.56       | 707                                 |
| 2.  | Argomulyo| 6.905        | 8.47        | 815                                 |
| 3.  | Glagaharjo| 3.803        | 7.95        | 478                                 |
| 4.  | Kepuharjo| 3.297        | 8.75        | 377                                 |
| 5.  | Umbulharjo| 5.296        | 8.26        | 641                                 |
|     | Total    | 29.592       | 47.99       | 3.018                               |

Source : Secondary Data Analysis, 2020

4.2 The Disaster Risk Level of Merapi Volcano Eruption in Cangkringan District

4.2.1 The Hazard Level of Merapi Volcano Eruption in Cangkringan District

The hazard level of Merapi Volcano eruption is divided into three levels which are low, medium and high. Cangkringan District has five villages, but not all of them are included in the Disaster Prone Areas map. The low hazard level does not exist in Cangkringan District. The moderate level of danger covers part of Argomulyo Village, part of Wukirsari Village, part of Kepuharjo Village and part of Umbulharjo Village. The high hazard level covers all of Glagaharjo Village and part of Argomulyo Village, part of Kepuharjo Village, part of Wukirsari Village and part of Umbulharjo Village.

| No. | Village  | Criteria | Large of KRB (Ha) | Large in percent | Score | Hazard Level |
|-----|----------|----------|-------------------|------------------|-------|--------------|
| 1.  | Wukirsari| KRB II   | 363.25            | 24.94            | 20    | Medium       |
|     |          | KRB III  | 105.25            | 7.22             | 30    | High         |
| 2.  | Argomulyo| KRB II   | 266.01            | 31.40            | 20    | Medium       |
|     |          | KRB III  | 326.47            | 38.54            | 30    | High         |
| 3.  | Glagaharjo| KRB III | 795.00            | 100              | 30    | High         |
| 4.  | Kepuharjo| KRB II   | 198.72            | 22.71            | 20    | Medium       |
|     |          | KRB III  | 567.36            | 64.84            | 30    | High         |
| 5.  | Umbulharjo| KRB II  | 532.48            | 64.46            | 20    | Medium       |
|     |          | KRB III  | 390.14            | 47.23            | 30    | High         |

Source : Secondary Data Analysis, 2020

4.2.2 The Vulnerability Level of Merapi Volcano Eruption Disaster in Cangkringan District

The results of the assessment of the total vulnerability variable to the eruption of Merapi Volcano in Cangkringan District are included in the high and medium categories. The high category includes five villages, namely Wukirsari Village, Argomulyo Village, Umbulharjo Village and parts of Glagaharjo Village and Kepuharjo Village. The medium category includes two villages, namely Glagaharjo and Kepuharjo villages. The factors that cause high vulnerability in Cangkringan District are mainly economic and physical vulnerability variables.
Table 4. The Distribution of Total Vulnerability in Cangkringan District

| No | Village    | Level of Total Vulnerability | Large (Ha) | %    |
|----|------------|-----------------------------|------------|------|
| 1. | Wukirsari  | High                        | 1.456      | 30.33|
| 2. | Argomulyo  | High                        | 847        | 15.65|
| 3. | Glagaharjo | High                        | 360.46     | 7.51 |
|    |            | Medium                      | 537.54     | 11.20|
| 4. | Kepuharjo  | High                        | 72.77      | 3.52 |
|    |            | Medium                      | 699.23     | 14.57|
| 5. | Umbulharjo | High                        | 826        | 17.22|
|    |            |                             | **4.799**  | **100**|

Data Analysis, 2020

4.2.3 Capacity Level of Merapi Volcano Eruption Disaster in Cangkringan District

The existing capacity in the Cangkringan District area in facing the eruption of Merapi Volcano is included in one criterion, namely high. This high level of capacity can be found in all villages in the Cangkringan District. The factor affecting the high capacity level in the area is that all capacity nodes are functioning properly.

Table 5. The Distribution of Capacity in Cangkringan District

| No | Village    | Capacity Level | Large (Ha) | %    |
|----|------------|----------------|------------|------|
| 1. | Wukirsari  | High           | 1.456      | 30.33|
| 2. | Argomulyo  | High           | 847        | 15.65|
| 3. | Glagaharjo | High           | 795        | 16.56|
| 4. | Kepuharjo  | High           | 875        | 18.24|
| 5. | Umbulharjo | High           | 826        | 17.22|
|    |            |                | **4.799**  | **100**|

Data Analysis, 2020

4.3 The Distribution of the Risk of Merapi Volcano Eruption in Cangkringan District

4.3.1 The Distribution of the Hazard of Merapi Volcano Eruption in Cangkringan District

Figure 1. Map of Disaster Prone Area in Cangkringan District

The Disaster Prone Area III covers part of Umbulharjo Village, part of Kepuharjo Village, part of Wukirsari Village, whole of Glagaharjo Village and part of Argomulyo Village. The village in Disaster Prone Area III is a village that has threats in the form of hot clouds, lava flows and also threats of throwing incandescent rocks and dense volcanic ash. The Disaster Prone Area II is located in part of Umbulharjo Village, part of Kepuharjo Village, part Wukirsari Village and part Argomulyo Village.
The village in Disaster Prone Area II is a village that has threats in the form of mass flows of lava as well as throwing materials and heavy ash rain.

4.3.2 The Distribution of Vulnerability of Merapi Volcano Eruption in Cangkringan District

![Vulnerability Distribution Map](image)

The results of the assessment of total vulnerability to the eruption of Merapi Volcano in Cangkringan District are included in the high and medium vulnerability category. The high category includes five villages, namely Wukirsari Village, Argomulyo Village, Umbulharjo Village and parts of Glagaharjo Village and Kepuharjo Village. The medium category includes two villages which are part of Glagaharjo and part of Kepuharjo villages. The factors that cause high vulnerability in Cangkringan District are mainly caused by economic and physical vulnerability variable.

4.3.3 Distribution of Capacity against the Eruption of Merapi Volcano in Cangkringan District

![Capacity Distribution Map](image)

The existing capacity in the Cangkringan Subdistrict area in facing the eruption of Merapi Volcano is included in one criterion, namely high. This high level of capacity can be found in all villages in the Cangkringan District. Factors affecting the high capacity level in the area are the presence of OPB, the existence of an early warning system, basic risk reduction factors and the existence of well-functioning disaster mitigation.
4.4 The Disaster Risk Level and Distribution of Merapi Volcano Eruption in Cangkringan District

Disaster risk in Cangkringan District is in all villages. The distribution of high-risk level is in part of Umbulharjo Village, part of Glagaharjo Village and part of Argomulyo Village. The distribution of medium-risk level is in part of Umbulharjo Village, part of Kepuharjo Village and part of Glagaharjo Village. The distribution of low-risk level is in part of Kepuharjo village, part of Wukirsari village and part of Argomulyo Village. The distribution of very low-risk level is in part of Wukirsari Village and part of Argomulyo Village.

5. Conclusion

The risk level of Merapi Volcano eruption in Cangkringan District has four levels which are high, medium, low and very low disaster risk levels. The distribution of high-risk level is in part of Umbulharjo Village, part of Glagaharjo Village and part of Argomulyo Village. The distribution of medium-risk level is in part of Umbulharjo Village, part of Kepuharjo Village and part of Glagaharjo Village. The distribution of low-risk level is in part of Kepuharjo Village, part of Wukirsari Village and part of Argomulyo Village. The distribution of very low-risk level is in part of Wukirsari Village and part of Argomulyo Village.

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