Risk Analysis of Sinabung Volcano Eruption in Karo, North Sumatera, Indonesia

Aldo Prayoga, Luciana Maorine Wita, Vernon Pinandhito
Undergraduate Student of Padjajaran University, Geological Engineering Faculty
aldoprayoga93@gmail.com

Abstract. Indonesia is set between 3 colliding active plates, i.e. Eurasia, Indo-Australia, and Pacific Plates. The collision of those plates give rise to many volcanoes in Indonesia, some of them are active, including Sinabung volcano. Sinabung Volcano is an A type volcano with its summit reaching 2460 masl. Sinabung Volcano has been active again since 2010, and its activity has been increasing since then until its latest eruption on 19 February 2018. Its volcanic activities, including its eruption is a threat to local residents in Karo Regency, which live around the volcano. The danger of the eruption includes volcanic ash, hot ash, pyroclastic flow, lahar flow, lava flow, poisonous gas, and ejected molten rock fragments. The purpose of this research is to analyze the threat index of each sub-districts in Karo region where Sinabung volcano is located, in case it erupts someday. The method for this research is secondary data analysis which includes Administrative Map, Disaster Prone Zone Map, Land Use Map, and Population Data. Risk Analysis Table is then produced from the compilation of the data, which shows the threat index of each sub-district. The Risk Analysis Table serves a guide to develop local disaster mitigation and to educate the local residents, providing a more directed and more prepared mitigation and evacuation. Sustainable Development Goals 11, especially in indicator 11.B, strongly implies that sustainable cities & communities require disaster risk reduction strategies. Based on the analysis, several sub-districts, i.e. Payung, Tiganderket, Simpang Empat, and Naman Teran are categorized as regions with high threat index.

1. Introduction
Indonesia is set between 3 colliding active plates, i.e. Eurasia, Indo-Australia, and Pacific Plates. The collision of those plates give rise to many volcanoes in Indonesia, most of them are a part of Ring of Fire. Having so many active volcanoes, from Aceh until Maluku, causes Indonesia to likely be susceptible of volcano eruptions. Therefore, mitigation is necessary to reduce the harm and the number of casualties.

Indonesia has 127 active volcanoes, including Sinabung Volcano. Sinabung Volcano is an A type volcano with its summit reaching 2460 masl. It is located in North Sumatera, in Karo Regency to be precise. Recorded not to experience eruption since the early of 17th century, Sinabung Volcano has been active again since 2010, and its activity has been increasing since then until its latest eruption on 19 February 2018. Due to its dangerous activities, Sinabung Volcano has been alerted to be at Warning level (4th Level) since 2 June 2018 [1] [2].
Sinabung volcanic activities, including its eruption is a threat to local residents in Karo Regency, which live around the volcano. The danger of the eruption includes volcanic ash, hot ash, pyroclastic flow, lahar flow, lava flow, poisonous gas, and molten rock ejection. Volcano eruption awareness should be acknowledged by local residents living around Sinabung Volcano. Therefore, Risk Analysis Table which categorizes each region based on their threat index is needed to educate local residents about the danger of Sinabung Volcano eruption.

Sinabung Volcano is located in Karo Regency which is occupied by plenty local residents. Its eruption might disrupt all human activities there. Worse, larger eruption might cause casualties and huge loss for the entire region.

This research aims to: 1. To identify the effects of Sinabung Volcano Eruption, 2. To produce Risk Analysis Table of Karo region, 3. To educate local residents by raising their awareness, and 4. To provide a more directed and more prepared mitigation and evacuation[3–5]

2. Data and Method

The method for this research is secondary data analysis which includes Administrative Map, Disaster Prone Zone Map, Land Use Map, and Population Data. Risk Analysis Table is then produced from the compilation of the data, which shows the threat index of each sub-district.

3. Result and Discussion

Sinabung Volcano is located in Karo Regency, North Sumatera. Administratively, the regency has 17 sub-district with its capital in Kabanjahe, as shown in the administration map (Figure 1 A).

![Figure 1. (A) Administration Map of Karo Regency (B) Land Use Map of Karo Regency](image)

| Sub-district Name | Land Use                          |
|------------------|-----------------------------------|
| Kabanjahe        | Forest, Agricultural Fields       |
| Berastagi        | Forest, Agricultural Fields       |
| Merdeka          | Forest, Agricultural Fields       |
| Dolat Rayat      | Forest, Agricultural Fields       |
| Payung           | Forest, Agricultural Fields       |
| Simpang Empat    | Forest, Agricultural Fields       |
| Bantanap         | Forest, Agricultural Fields       |
| Munte            | Forest, Agricultural Fields       |
| Tiganderet       | Forest, Agricultural Fields       |
| Naman Teran      | Forest, Agricultural Fields, Lake |
| Merek            | Forest, Agricultural Fields       |
| Tiga Binanga     | Forest, Agricultural Fields       |
| Laubaing         | Forest, Agricultural Fields       |
| Mardingting      | Forest, Agricultural Fields       |
| Juhar            | Forest, Agricultural Fields       |
| Kuta Buluh       | Forest, Agricultural Fields       |

| Sub-district Name | Population | Area  | Density (lives/km^2) |
|------------------|------------|-------|---------------------|
| Kabanjahe        | 64.745     | 44.7  | 1450.1              |
| Berastagi        | 43.494     | 30.5  | 1426.0              |
| Merdeka          | 36.607     | 44.2  | 308.1               |
| Dolat Rayat      | 84.82      | 32.3  | 263.0               |
| Payung           | 11.079     | 47.2  | 234.5               |
| Simpang Empat    | 19.440     | 93.5  | 208.0               |
| Barusjahe        | 22.593     | 128.0 | 176.5               |
| Tigapanah        | 29.976     | 186.8 | 160.4               |
| Munte            | 20.127     | 125.6 | 160.2               |
| Tiganderet       | 13.474     | 86.8  | 155.3               |
| Naman Teran      | 13.083     | 87.8  | 149.0               |
| Merek            | 18.458     | 125.5 | 147.1               |
| Tiga Binanga     | 20.346     | 160.4 | 126.9               |
| Laubaing         | 18.110     | 252.6 | 71.7                |
| Mardingting      | 17.445     | 267.1 | 65.3                |
| Juhar            | 13.540     | 218.6 | 62.0                |
| Kuta Buluh       | 10.823     | 195.7 | 55.3                |

| Karo Regency     | 358.823    | 2127.3| 168.7               |
Based on the land use map (Figure 1 B), Karo Regency is dominated by forest, swamp, rice fields and residency spreading unevenly to all sub-district. Karo Regency has 2 major cities with dense population, i.e. Kabanjahe City, and Berastagi City. Moreover, the population statistics of Karo Regency [6,7] shows the local Sinabung volcanic eruption is a threat to local residents in Karo Regency, which live around the volcano. The danger of the eruption includes volcanic ash, hot ash, pyroclastic flow, lahar flow, lava flow, poisonous gas, and molten rock ejection. (Figure 3 B).

![Image](image1.png)

Figure 2. (A) Population Density Map of Karo Regency (B) Disaster Prone Zone Map (BNPB)

| Zone | Danger Description |
|------|--------------------|
| III  | Zone is very likely to be affected by hot cloud, dense ash fall, poisonous gas, pyroclastic flow, lava flow, and ejected molten rock fragments |
| II   | Zone is likely to be affected by hot cloud, ash fall, lava flow, and ejected molten rock fragments |
| I    | Zone is likely to be affected by lahar flow and or ash fall |

Generally, regions around Sinabung Volcano are likely to be affected by ash fall which intensity is inversely proportional to the range in which the regions are located from Sinabung Crater.

Also generally, the closer a region to the crater, the more susceptible it is to a more harmful danger of the volcano eruption. Region closest to the Sinabung Crater is very likely to be affected volcanic ash, hot ash, pyroclastic flow, lahar flow, lava flow, poisonous gas, and molten rock ejection. In this case, the closest region are the most vulnerable. But what really determines the threat index of a region is its location based on the Disaster Prone Zone Map, which disaster in this case is Sinabung Volcano Eruption.

Risk Analysis Table is a method to determine threat index of a region based on the consideration of population density, land use, and disaster prone zone of a region. The table is produced by the interpretation of compiled maps and data, including Disaster Prone Zone Map, Land Use Map, and Population Density Data. From the table, the threat index of each region can vary starting from low, medium, high, until very high. In this case, Risk Analysis Table can show regions with the highest threat index to the ones with the lowest, therefore giving at least a hint on a better mitigation and evacuation preparation, by prioritizing the sub-districts with the highest threat index if an eruption suddenly takes place.

In the case of natural disaster, government’s direction carry big effects; naturally, they are the one who has the obligation, along with BNPB, to ensure the safety of people. Thus, they must make wise decision in securing the people. Still in the case of natural disaster, central government usually sends material and financial support to the local governments, being the mayor each sub-district; and each of them will use the supports for the good of their people; the support are given through appropriate procedure. Usually, different actions are taken based on the position of the regions they’re dealing with. For instance, the closer a region to the center of the eruption must get the top priority, which is not always the case. Thus, this research will provide a hint on which sub-district needs the most immediate support from the government. As governmental system and support are regulated by local
government, in local area; they will be wisely given depending on each threat index. Eventually, the table can reduce the worst harm caused by Sinabung volcano eruption.

In order to achieve two of sustainable develop-ment goals; i.e. Goal 3: Good Health and Well-Being for People and Goal 11: Sustainable Cities and Communities; It’s important to secure the life of people and the environment they’re living in, in this case in a specific focus; hence, proper mitigation is required.

Table 4. Risk Analysis Table

| Sub-district Name | Population Density (people/km²) | Land Use | Danger Description | Threat Index |
|-------------------|---------------------------------|----------|--------------------|--------------|
| Payung            | 234.5                           | Residential, Forest, Swamp, Rice Fields | Zone is very likely to be affected by hot cloud, dense ash falls, poisonous gas, pyroclastic flow, lava flow, and ejected molten rock fragments | Very High |
| Taman Teri        | 155.5                           | Residential, Forest, Swamp, Rice Fields | Zone is very likely to be affected by hot cloud, dense ash falls, poisonous gas, pyroclastic flow, lava flow, and ejected molten rock fragments | Very High |
| Simpang Empat     | 207.8                           | Residential, Swamp, Rice Fields | Zone is very likely to be affected by hot cloud, dense ash falls, poisonous gas, pyroclastic flow, lava flow, and ejected molten rock fragments | Very High |
| Naman Teran       | 148.8                           | Residential, Forest, Rice Fields | Zone is very likely to be affected by hot cloud, dense ash falls, poisonous gas, pyroclastic flow, lava flow, and ejected molten rock fragments | High |
| Tiga Bungat       | 123.9                           | Residential, Forest, Rice Fields | Zone is very likely to be affected by hot cloud, dense ash falls, poisonous gas, pyroclastic flow, lava flow, and ejected molten rock fragments | High |
| Munte             | 180.4                           | Residential, Forest, Swamp, Rice Fields | Zone is very likely to be affected by hot cloud, dense ash falls, poisonous gas, pyroclastic flow, lava flow, and ejected molten rock fragments | High |
| Kebunbule         | 145.0                           | Residential, Forest, Swamp, Rice Fields | Zone is very likely to be affected by hot cloud, dense ash falls, poisonous gas, pyroclastic flow, lava flow, and ejected molten rock fragments | High |
| Berastagi         | 243.0                           | Residential, Forest, Swamp, Rice Fields | Zone is very likely to be affected by hot cloud, dense ash falls, poisonous gas, pyroclastic flow, lava flow, and ejected molten rock fragments | High |

Based on the interpretation, Payung, Tigan Derket, Simpang Empat, and Naman Teran Sub-districts are categorized as regions with the very high threat index. While Tigabinanga, Munte, Kabanjahe, and Berastagi are categorized as regions with high threat index. Merdeka, Tigapanah, Dolat Rakyat, and Merek sub-districts are categorized as regions with medium threat index. And Maringding, Laubaleng, Juhar, dan Kutabulu Sub-districts are categorized as regions with low threat index.

4. Conclusion

The eruption of Sinabung Volcano is capable to cause casualties and huge loss for the Karo Regency. Thus, by using Risk Analysis Table, this research aimed to identify the threat index of each regions in
Karo Regency where Sinabung Volcano is set. In order to achieve two of sustainable development goals; i.e. Goal 3: Good Health and Well-Being for People and Goal 11: Sustainable Cities and Communities; It’s important to secure the life of people and the environment they’re living in, in this case in a specific focus; hence, proper mitigation is required. Risk Analysis Table serves a guide to develop local disaster mitigation and to educate the local residents, providing a more directed and more prepared mitigation and evacuation. Risk Analysis Table will provide a hint on which sub-district needs the most immediate support from the government. Based on the result of the research, several sub-districts, i.e. Payung, Tiganderket, Simpang Empat, and Naman Teran are categorized as regions with high threat index, as they are affected by hot ash, dense ash fall, poisonous gas, pyroclastic flow, lava flow, and ejected molten rock fragments.

References
[1] BNPB 2015 *Peta Kawasan Rawan Bencana dan Rupabumi Gunungapi Sinabung* (Badan Nasional Penanggulangan Bencana)
[2] National Disaster Management Authority (BNPB) 2012 Badan nasional penanggulangan bencana (bnpb)
[3] Dicky M, Haerani E, Shibayama M, Ueshima M, Kagawa N and Hirnawan F 2015 Disaster Awareness Education in Schools around Geological Hazards Prone Areas *Eng. Geol. Soc. Territ.* 6 107–112
[4] Shibayama M, Kagawa N, Ueshima M and Muslim 2012 Earthquake and Tsunami Disaster Prevention Education for Children in Indonesia *Abstract and Technical Program of the 34th International Geological Congress (IGC)* (Brisbane, Australia: Session of Geoscience Education) p 103
[5] G.O. M, F.N M, E H and and Sophian R.I M D 2017 Disaster Awareness Campaign of Indonesian Boy Scout Gerakan Pramuka for Students *Proceeding of the 2nd Join Conference of Utsunomiya University, Japan and Universitas Padjadjaran, Indonesia* pp 42–47
[6] Badan Pusat Statistik 2014 *Statistik Populasi Kota Karo*
[7] Pemda Kabupaten Karo 2013 *Peta Administrasi Kabupaten Karo Provinsi Sumatera Utara*