Volcanic hazard analysis of sinabung volcano eruption in karo north sumatra indonesia

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Abstract. Mount Sinabung is one of active volcano in Karo North Sumatra Indonesia. Before 2010, Sinabung was categorized as a dormant volcano. After eruption that happened on August 29, 2010, Sinabung increased its level as active volcano. The eruption of Sinabung occured again in September 2013 until now that has not stopped its activity. The research purposes are to analyze the characteristics of volcanic hazard of Sinabung Volcano eruption in Karo and to know the distribution of the characteristics of volcanic hazard of Mount Sinabung.
The characteristics of volcanic eruption hazard were analyzed based on geomorphological characteristics because volcanic eruption is one of geomorphological process. Moreover, the geomorphological characteristics were analyzed based on satellite image interpretation, geological map interpretation, and field survey. Delineation of volcanic hazard and data analysis used Geographic Information System (GIS). Moreover, the research results were analyzed as descriptively and spatially. The results show that the volcanic hazard characteristics of Sinabung consist of primary and secondary hazards. The primary hazards of Sinabung eruption are pyroclastics flow (hot clouds), pyroclastic fall (volcanic ash and rocks), and lava flows. Generally, the primary hazard threatens the eastern, southern, southeastern and southwestern regions of Sinabung Volcano. Meanwhile, the secondary hazard of Sinabung eruption is the lahar flow along the Lau Borus River and other rivers which disgorged at Mount Sinabung.

1. Introduction

There are many volcanoes in Indonesian which occurred by subduction of three major plates namely The Eurasian, Hindia-Australian, and West-Pasific Plate [1]. The South-east Asia plate is moved by 1 cm/year to the south – east [1]. Furthermore, the Hindia-Australian plate moved to the north by 7 cm/year and the West-Pasific plate moved by 9 cm/year to the west. In addition, the Hindia-Australian plate which is part of Eurasian plate sub-ducts under the Sumatra and the Java islands [2], [3],[4]. The intensity of tectonic-plates movement can affect the activities of volcanoes. Otherwise, volcanoes can give impact to the formation of the earth's ocean, continent and atmosphere throughout history [5].

Currently, there are 129 active volcanoes and 500 inactive volcanoes in Indonesia. The active volcanoes in Indonesia reaches 13% of the whole active volcanoes in the world. Then, 70 volcanoes

among them are volcanoes which prone to erupt and 15 volcanoes are critical volcanoes [6]. Moreover, Indonesia is located at Pacific Ring of Fire which is active volcanoes belt. Thus, volcanic eruption often occurred in Indonesia.

Volcanic eruptions occur when gas and lava are discharged from a volcanic vent. Any kind of volcanic eruption is capable to create dangerous and destructive phenomena. In Indonesia, volcanic eruption have become a serious threat. Recently, the incidence of volcanic eruption increase significantly. One of the incident is Sinabung volcanic eruption in Karo Regency, Sumatra Utara. The Sinabung volcanic eruption which happened on 29 August 2010 was initial phenomenon of Sinabung volcano activity after around 400 years did not show eruption activity. The increased of Sinabung activity was occurred after the explosive eruption which eject volcanic materials. Due to this phenomenon, the type of Sinabung was changed from dormant to active.

After eruption in 2010, Sinabung started to erupt in September 2013 with high intensity. On 24 November 2013, the status of Sinabung was changed from level III (standby) to level IV (caution). In February 2014, Sinabung erupted pyroclastic flow which moved to the south-east. This incident caused the death of 16 victims in Sukameriah village while on 21 May 2016, pyroclastic flow also caused 9 deaths in Gamber village. Until now, Sinabung is still erupting.

Volcanic eruption is one of geomorphological processes. The study of geomorphology deals with the physical surface characteristics. Based on the physical surface characteristics in Sinabung region, it can be analyze hazard of Sinabung eruption. Consequently, geomorphological approach can be used to analyze the hazard of Sinabung Volcano eruption. Figure 1 illustrates the location of Sinabung Volcano in Karo Regency, North Sumatra Province.

Figure 1. Location of Sinabung Volcano in Karo Regency, North Sumatra Province

2. Research Objectives

The research objectives are: (1) to analyze the characteristics of eruption hazard of Sinabung Volcano and (2) to know the distribution of the characteristics of eruption hazard of Sinabung Volcano.

3. Methods

The research methods are surveying, sampling and qualitative. Sample of this study was taken by purposive sampling. The geomorphological characteristics were analyzed based on satellite image (Google Earth) interpretation, geological map interpretation, and field survey. Delineation of landform unit and data analysis used Geographic Information System (GIS), i.e. Arc GIS software. Characteristics of volcanic eruption hazard were analyzed based on geomorphological characteristics as volcanic eruption is one of geomorphological processes. Furthermore, the research results were analyzed as descriptively and spatially.

4. Result and Discussion

4.1. The eruption hazard characteristics of Sinabung

The eruption hazard characteristics of Mount Sinabung consist of primary and secondary hazards. The primary hazards of eruption of Mount Sinabung include the pyroclastic flow (hot clouds), lava flows, and pyroclastic fall (volcanic ash and rocks).

Hot clouds of Sinabung volcano eruption has killed 16 people in Sukameriah Village in 2014 and 9 people in Gamber Village in 2016. Region of Sukameriah Village and Gamber Village are included the red zone of Sinabung volcano eruption. They are located only 3 km from the peak of Sinabung volcano. Furthermore, Sukameriah Village was buried by pyroclastic material. In addition, Bakerah Village and Simacem Village are also buried by the pyroclastic material. The size of pyroclastic material are varied from <0.063 mm to >64 mm and spread in some areas namely south-east and south slope of Sinabung.

Additionally, lava flow also occurred in the southern part of Sinabung volcano especially in the peak and middle slope of Sinabung. Lava flow which formed in Sinabung has high viscosity. As the result, lava was flowed with low velocity. This can be seen from the lava flow located at the top of Sinabung as presented in Figure 2a. The pattern of lava flow of Mount Sinabung which has occurred in the past shaped like flower petals. The flow of lava showed different direction in different eruption periods. Meanwhile the Sinabung eruption which happened in 2013 until now result lava flow which lead to south and south-east of Sinabung. The lava flow pattern in the can be seen in Figure 2b.

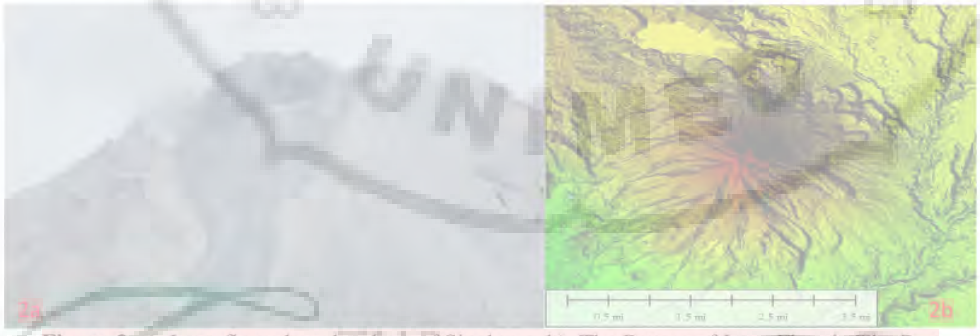

Figure 2. a). Lava flowed on the slope of Sinabung b). The Pattern of Lava Flow in The Past

The third character of volcanic hazard of Sinabung is volcanic ash. The distribution of volcanic ash follows the wind direction. Areas that are often exposed to volcanic ash are east, southeast, and southern volcanoes of Sinabung. Based on the historical eruption event, if the eruption is small, the Namanteran area is always exposed to volcanic ash. In addition, if the eruption is moderate, Berastagi and Kabanjahe areas are exposed to volcanic ash. However, if the eruption is large, volcanic ash spread up to the city of Medan. The description of the area affected by volcanic ash of Sinabung volcano as presented in Figure 3a and Figure 3b.

Figure 3. a. Agricultural land damaged by volcanic eruption Sinabung in Gurukinayan area, 3b). The settlement was damaged by the volcanic eruption of Sinabung in the Sigarang-garang area

The secondary hazards of Sinabung eruption is the lahar which flow along the Lau Borus River. Lahar flow also occurred in Tiganderket district. Lahar is devastating and it moves swiftly. Lahar flow is came from pyroclastic material which is located on the slope of the east–southeast-south. Lahar flow is formed if the heavy rainfall detach the pyroclastic material. Then, lahar will flow to down area. The characteristics of lahar in Sinabung is size of the material consist of sand and rock fragment. This materials mix together with overland flow and go down from step slope area to plain area. Lahar flowed along Lau Borus River destroyed agricultural land and roads. Moreover, lahar flow also destroyed agricultural land, roads, settlement, and bridges in Tigaderket district. The description of the area affected by lava flows is presented in Figure 4a and Figure 4b.

Figure 4. a). Sukatendel Village, Tiganderket District was affected by lahar flow Figure, 4b). Lahar flow around the Lau Borus River

4.2. The distribution of eruption hazard characteristics of Sinabung

Generally, the distribution of primary hazard of Sinabung eruption were in south and south-east slope of Sinabung. Meanwhile, the secondary hazard of Sinabung spread on all part of Sinabung slope especially in some rivers which disgorged in Mount Sinabung. The Figure 5 illustrates the distribution of eruption hazard characteristics of Sinabung. Based on the geomorphological processes of Sinabung eruption, the main danger threatens the eastern, southern, southeastern and southwestern regions of Mount Sinabung.

5. Conclusion

The primary hazards of eruption of Mount Sinabung consist of the pyroclastic flow (hot clouds), pyroclastic fall (volcanic ash and rocks), and lava flows. While the secondary hazards of Sinabung eruption is the lahar flow. Moreover, the main danger threatens the eastern, southern, southeastern and

southwestern regions of Mount Sinabung. Consequently, these region are higher hazard than the other region of Mount Sinabung.

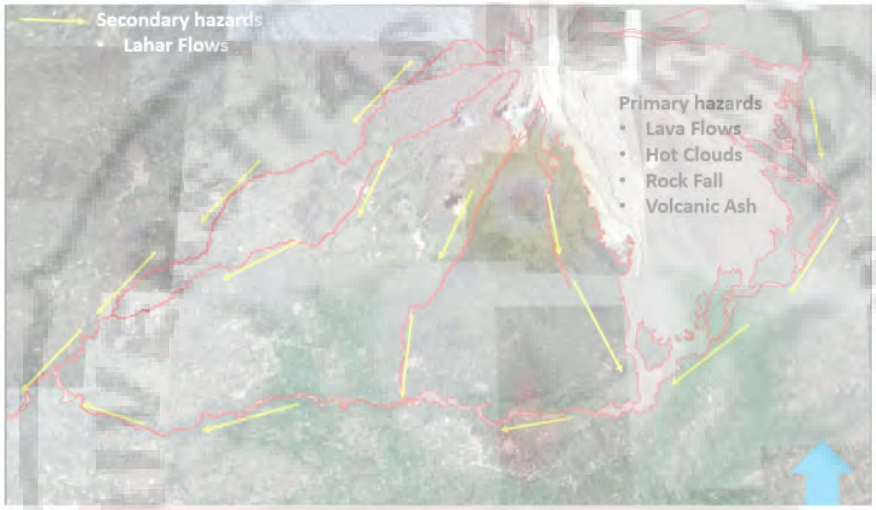

Figure 5. The Distribution of Eruption Hazard Characteristics of Sinabung

6. Acknowledgment

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