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ZONING OF SCHOOL VULNERABILITY TO SINABUNG ERUPTIONS IN KARO DISTRICT, NORTH SUMATRA PROVINCE, INDONESIA

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Abstract. This study aims to determine the school vulnerability around Sinabung. This research was conducted in May to August 2018. Spatial analysis was used to determine school vulnerability of Sinabung eruptions. School vulnerability from ash and school vulnerability from eruption area was determined with buffering. There was three categories school vulnerability, namely high, medium and low. It is known that there are 30 schools into the Sinabung volcanic eruption prone zone, 10 schools are in the volcanic lava flow prone zone, 44 schools are in the vulnerable zone of the Sinabung volcano, 5 schools are affected by lava flows, and 6 schools must be relocated due located in the high vulnerability zone of Sinabung volcano. The Ministry of Education and Culture has just established and implemented a special disaster prevention education curriculum at all school levels since the 2011-2012 academic year.

1. Introduction

Indonesia lies in the meeting of four active moving plates (Figure 1.), namely the Eurasian Plate which moves relatively southeastward at the speed of approximately 0.4 cm/year, the Indo-Australian Plate which moves relatively northward at the speed of approximately 7 cm/year, the Pacific Plate which moves relatively westward at the speed of approximately 11 cm/year and the Philippine Plate which moves relatively northwestward at the speed of approximately 8 cm/year (Minster and Jordan, 1978 in Yeats et. al [1]).

Based on tectonic province, Indonesia can be divided into two regions, namely the western part of Indonesia which involves the interaction of two plates, namely the Eurasian Plate and the Indo-Australian Plate and the eastern part of Indonesia which involves the interaction of three plates, namely the Indo-Australian Plate, Pacific Plate, Philippines Plate and several microcontinent. Thus the tectonic arrangement of eastern Indonesia is more complex than western Indonesia. The meeting of the four active moving plates resulted in the form of subduction zones, prismatic accretion zones, magmatic arcs, face basins, back basins, and geological structure patterns (Figure 1.) [2].

The plates move and collide with each other so that the Indo-Australian Plate slides down the Eurasian Plate. The subduction of the Indo-Australian Plate that moves north with the Eurasian Plate moving south causes an earthquake line and active volcano sequence along the islands of Sumatra, Java, Bali and Nusa Tenggara, turning north to Maluku and North Sulawesi, parallel to the second subduction route plate. These plate tectonics creates 500 mountains, 129 of which are still active [3]. Therefore Indonesia is a disaster-prone area. There are at least 12 disaster threats grouped in geological disasters,



hydrometeorological disasters and anthropogenic disasters. The geological disasters consist of earthquake, tsunami, volcano, ground/landslide movement). The hydrometeorological disasters consist of floods, flash floods, droughts, extreme weather, extreme waves, forest and land fires. While the anthropogenic disasters consist of epidemics disease and failed technology-industry accidents. Indonesia's Disaster Risk Index data shows that there were 205 million people living in disaster-prone areas in 2013 and disasters has increased significantly in the last decade [4].

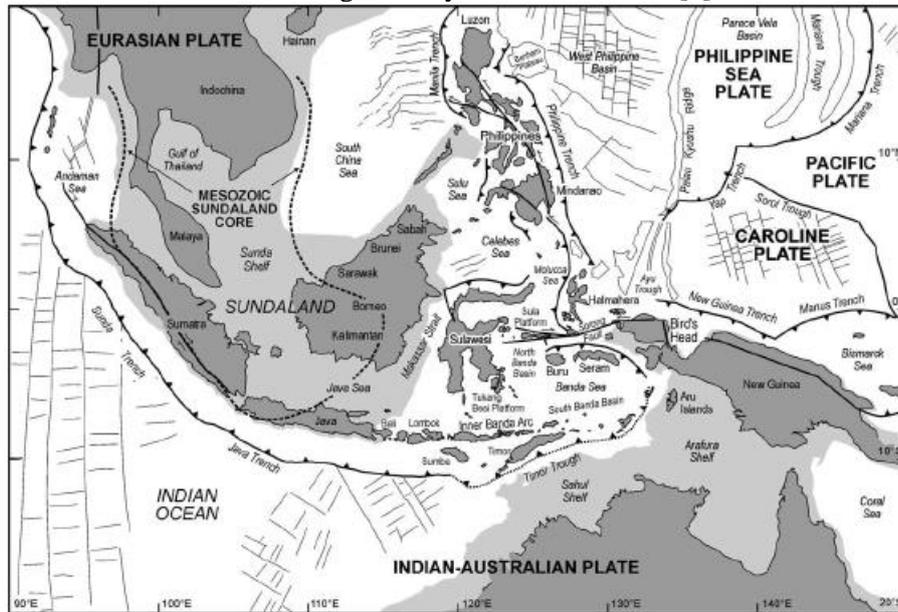


Figure 1. Tectonic arrangements in the Indonesian Archipelago [5]

The Sumatra region is characterized by a large number of earthquakes at the boundaries between the subducting Indo-Australian Plate, the Sumatra Fault zone and several active volcanoes that are lined up along this fault zone. It has been suggested that some volcanoes in Sumatra have shown increases in volcanic activity possibly related to tectonic earthquakes. While, Sinabung is one of volcanoes located in Sumatra that began to erupt on August 27, 2010, producing ash columns to 5 km asl and prompting evacuation of surrounding communities. Renewed phase was accompanied by eruptions happen in September 2013 and the eruption still continues after now, generating pyroclastic flows and lahars [6]; [7], [8]. Therefore this study aims to determine the school vulnerability around Sinabung.

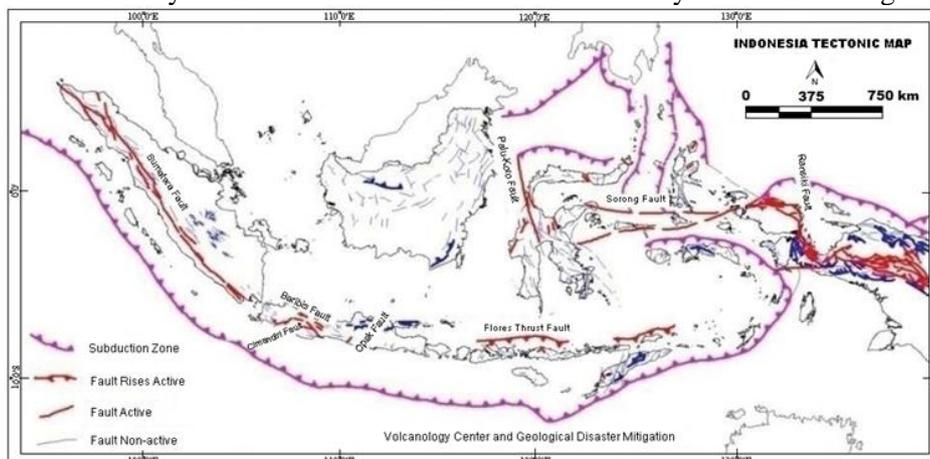


Figure 2. Active Fault Distribution and Destructive Earthquake Centers in Indonesia [9]

2. Research Method

Study area in this research was located around Sinabung Vulcano in Karo District, North Sumatra province, Indonesia, 40 km northwest of the Lake Toba caldera (Figure 3.). This research was conducted in May to August 2018. There have been 12 eruptions data since 2010 that was obtained from National Disaster Management Board. There was 30 school in disaster-prone, 10 school in eruption area, and 42 school in volcanic ash that was obtained from the education office. Spatial analysis was used to determine school vulnerability of Sinabung eruptions. School vulnerability from ash and school vulnerability from eruption area was determined with buffering. There was three categories school vulnerability, namely high, medium and low.

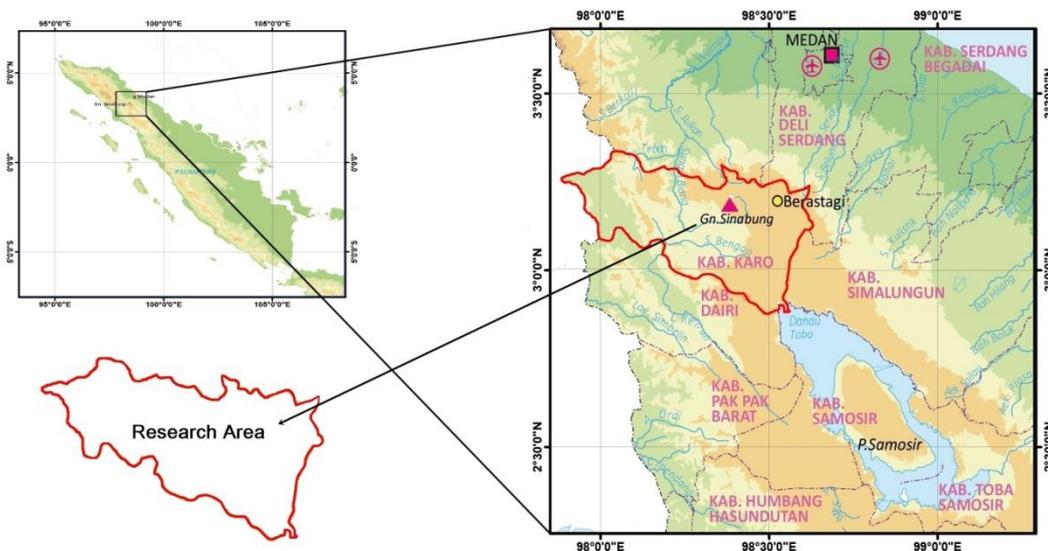


Figure 3. Research Area

3. Result and Disussion

History of the Sinabung Eruption

Sinabung volcano is a small stratovolcano 2460 m in height. Sinabung vulcano have unik phenomenon where changed from “B type” to “A type” volcano since the first historic eruptions in 2010 which previously was dormancy. This situation affected the society around Sinabung because it had not erupted in historic time (i.e., post- 1600 CE). Exacly, in August –September 2010 marked the first historic eruptions at Sinabung volcano, Indonesia, producing ash columns to 5 km asl and prompting evacuation of surrounding communities [6]. The Indonesian Center for Volcanology and Geological Hazard Mitigation (CVGHM) immediately issued a warning, and a second explosion occurred two days later on August 29 2010. This led to the evacuation of over 22,000 people residing at distances of < 6 km from the summit of the volcano [10]. Sinabung was again accompanied by eruptions beginning September 15, 2013. The ensuing eruption sequence has included phreatomagmatic eruptions, explosive magmatic eruptions, and persistent lava effusion. In late 2013, as eruption frequency increased, seismicity increased, and SO₂ continued to be detected [11].

In 2014, Mount Sinabung continued to experience the same conditions as in previous years, a series of eruptions and volcanic ash that increased the number of dead and lost and displaced victims. Since January 2014, pyroclastic flows have occurred repeatedly as part of the eruptive processes [12]. Base on the data of National Board for Disaster Management (BNPB) shown that there were 11,113 people displaced due to the eruption of Mount Sinabung in 2015. In 2016 the Sinabung volcano erupted again and resulted in 9 deaths and 15,508 people were displaced. Throughout 2017, the Sinabung Volcano continued to experience eruptions, recorded 4 eruptions this year. In May 2017, the status of Sinabung Mountain was increased to the alert marked by eruptions and hot clouds, the material bursts from the

eruption reached 4 kilometers, resulting in thousands of residents still must live in refuge. Whereas in 2018 one eruption was recorded and resulted in 100 residents having to evacuate to safer places [13].

Eruptions Area

Sinabung eruption-prone areas are divided into 3 zones, the eruption zones are high, medium, low, and there are lava flow zones (fig. 4). There are several sub-districts included in the Sinabung volcano eruption zone, Simpang Empat sub-district, Payung sub-district, Munte sub-district and Tiga Binanga sub-district. Simpang Empat district is the largest area affected by the Sinabung volcano eruption because it is right in the Sinabung volcano. Sinabung lava flows flow to the southeast and south as far as ± 5 km. There for, Bekerah Village, Simacem Village and the Tonggal Kuta Village are the villages most affected by the Sinabung Volcano eruption, because they are in the high zone of the Sinabung Volcano eruption.

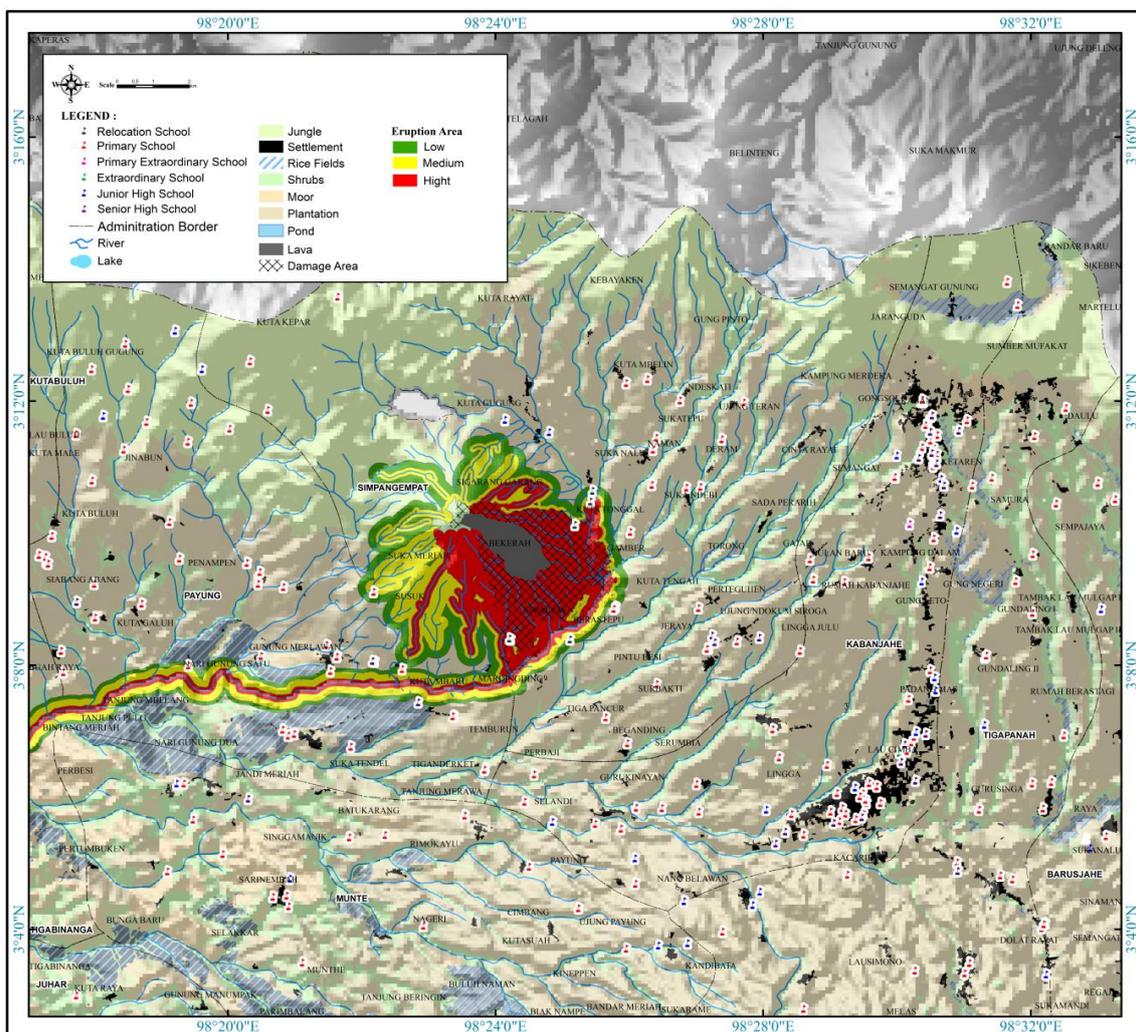


Figure 4. Eruptions Area

There were many eruptions since 2010. As a result, during the 2010-2018 eruption period 160,944 residents were victims of the Sinabung volcano eruption. In the period 2010-2018, the Sinabung volcano has experienced 12 eruptions. Most eruptions occurred in 2017 with a total of 4 eruptions (Table 1.).

Table 1. Data of victims of the Sinabung Eruption in 2010 to 2018

Year	Number of Events	Fatalities		
		Died and Lost	Injured	Suffer and Evacuate
2010	2	4	405	58,756
2013	2	0	0	34,567
2014	1	17	0	33,210
2015	1	0	0	11,113
2016	1	9	0	15,508
2017	4	0	0	7,255
2018	1	0	0	100
Amount	12	30	405	160,509

Based on table 1., it is known that the total casualties caused by this disaster were as many as 30 dead and missing, 405 injured and 160,509 victims suffering and displaced. The year 2014 was the highest number of deaths and lost victims, as many as 17 people were declared dead and missing, while the injured victims, suffered and displaced most were recorded in the 2010 eruption with 405 injured and as many victims displaced as many as 58,756 people [13].

Volcanic Ash hazard

Sinabung vulcano not only emits lava but also volcanic ash as far as ± 5 km to the southeast-south. As a result of this eruption there were 6 sub-districts around Mount Sinabung namely Naman Teran District, Simpang Empat District, Merdeka District, Dolat Rayat District, Barusjahe District, and Berastagi District which were exposed to volcanic ash [14]. Zoning of volcanic ash aversion is divided into 3 zones, namely the red zone with a high level of volcanic ash avalanche, a yellow zone with moderate avalanches and a low rate of green zone (fig. 5).

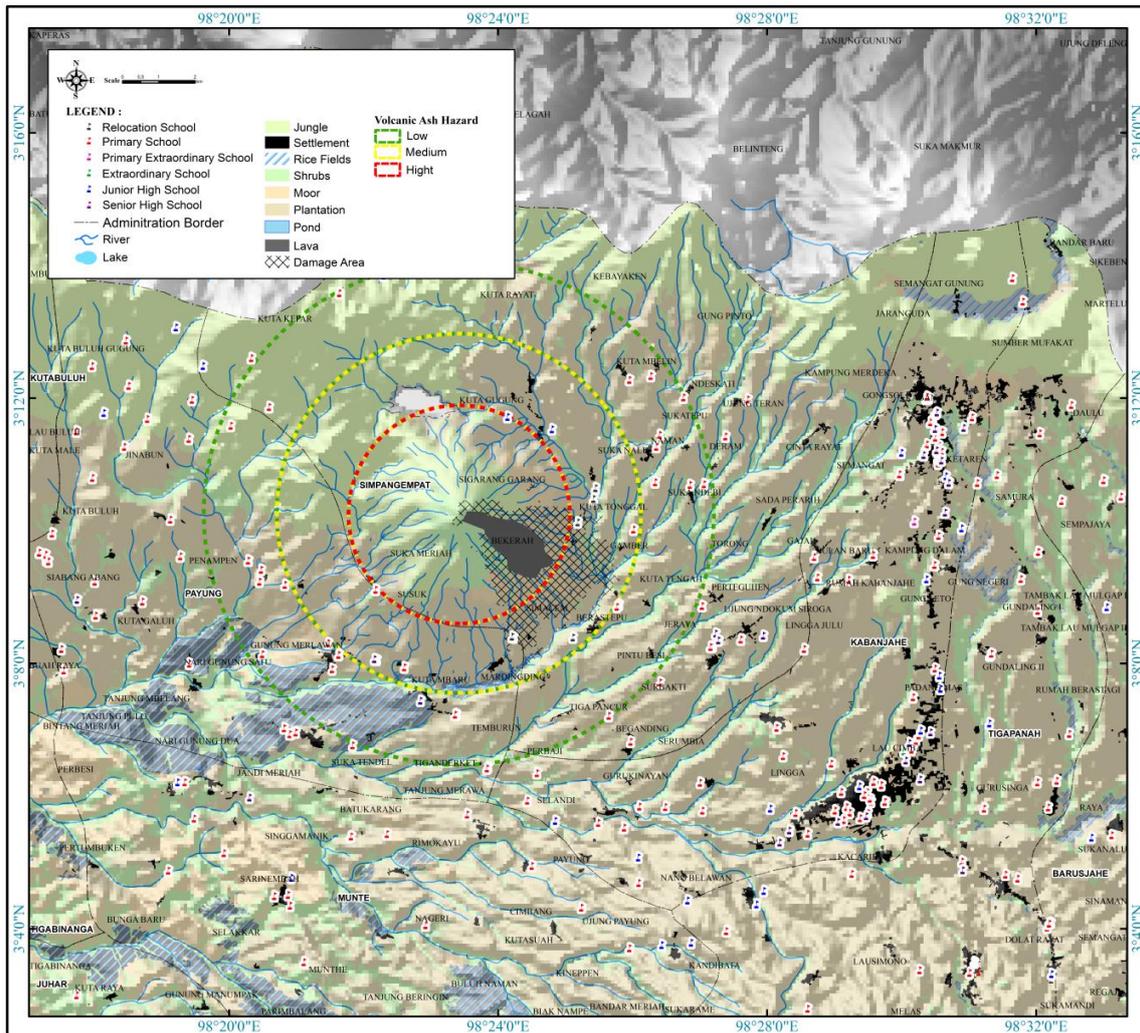


Figure 5. Volcanic Ash Hazard

The results of Sinabung volcanic ash analysis containing S elements ranged from 0.05 to 0.32%, Fe ranged from 0.58 to 3.1%, Pb ranged from 1.5 to 5.3%, while for the content Heavy metals such as Cd, As, Ag and Ni are not detected or are so low that they are not harmful. The element S (sulfur) is high in fresh ash, but when washing (exposed to rain) the value of S will decrease [15]. Simpang Empat sub-district is a sub-district in the red zone, where there are several villages affected by volcanic ash, such as Sigarang-garang village, Suka Meriah village, Susuk village and Bekerah village. As a result of the volcanic ash avalanche caused by the eruption of the Sinabung volcano, ± tens of thousands of hectares of people's plantations have failed to harvest due to volcanic ash.

Eruptions Area and Volcanic Hazard

The Sinabung eruption not only caused adverse impacts on plantation and agricultural land but also had a negative impact on people's activities. This seems like teaching and learning activities in schools must also be stopped temporarily due to some schools being directly affected by the volcanic eruption. Figure 6. shows the distribution of schools around Sinabung volcano.

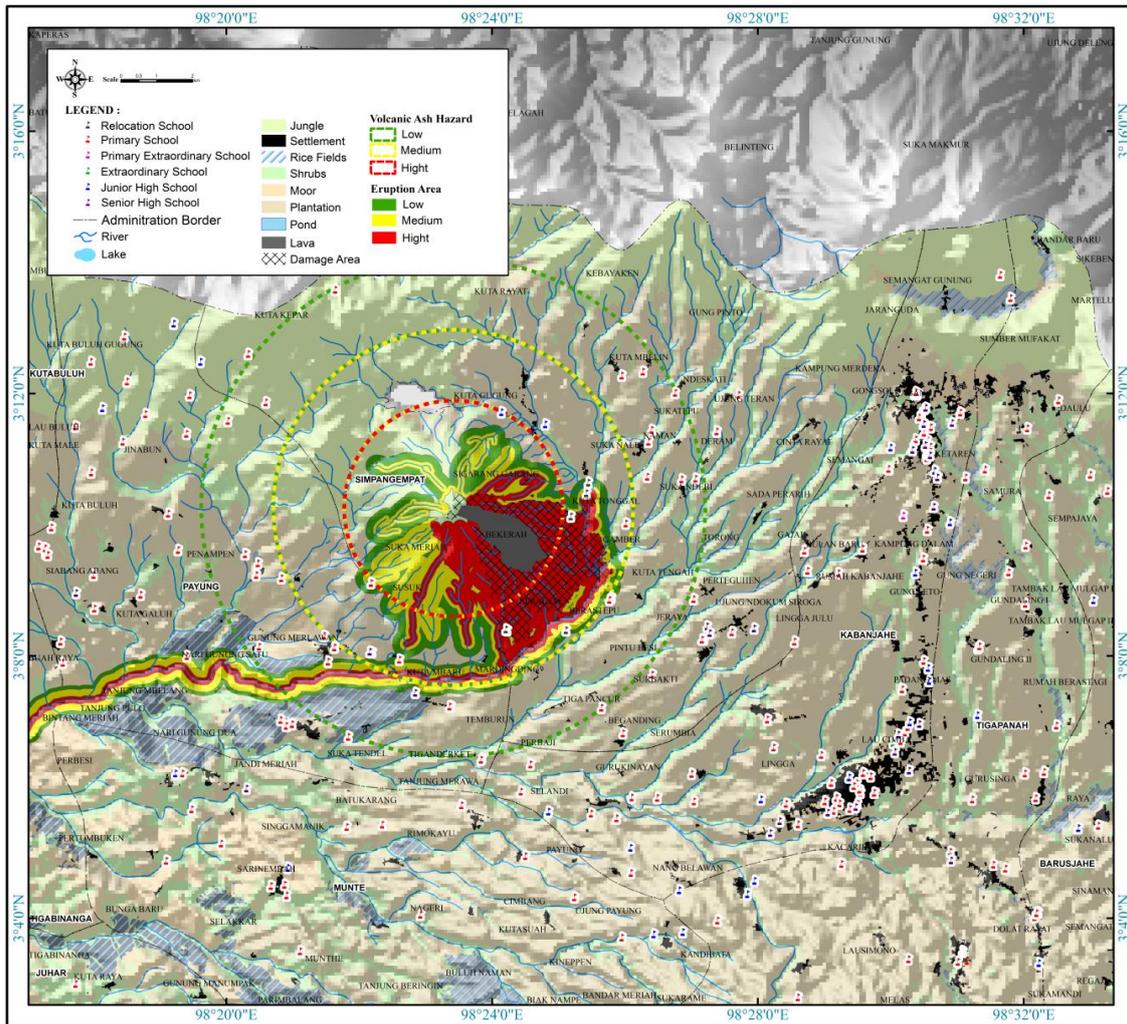


Figure 6. Eruptions Area and Volcaninc Ash Hazard

Based on figure 6, it is known that there are 30 schools into the Sinabung volcanic eruption prone zone, 10 schools are in the volcanic lava flow prone zone, 44 schools are in the vulnerable zone of the Sinabung volcano, 5 schools are affected by lava flows, and 6 schools must be relocated due located in the high vulnerability zone of Sinabung volcano. Many students are temporarily studying at a nearby school because their school cannot be used to study. In addition, students also feel traumatized by tremors, rumbling sounds and also sickness due to inhaling volcanic ash.

Considering that Indonesia as a country that is very vulnerable to natural disasters, efforts have been made to improve the resilience of its people to natural disasters. In the education sector, since the 2011-2012 academic year, the Ministry of Education and Culture has just established and implemented a special disaster prevention education curriculum at all school levels from elementary schools (students aged 7-12 years) to high and lower secondary schools (students with age 13-18 years). However, disaster in the education curriculum is still general. This needs to be adjusted to natural disasters in each region. Therefore, schools around Sinabung necessary to provide specific material on hate related to the disaster of the Sinabung eruption. This policy has an immediate goal to make children safer during disasters and to prepare them as agents of change who are able to spread knowledge to a larger community, especially for their own families.

4. Conclusion

Sinabung volcano changed from “B type” to “A type” volcano since the first historic eruptions in 2010 which previously was dormancy. Sinabung lava flows flow to the southeast and south as far as ± 5 km. There for, Bekerah Village, Simacem Village and the Tonggal Kuta Village are the villages most affected by the Sinabung Volcano eruption. Simpang Empat sub-district is a sub-district in the red zone, where there are several villages affected by volcanic ash, such as Sigarang-garang village, Suka Meriah village, Susuk village and Bekerah village. Six schools must be relocated due located in the high vulnerability zone of Sinabung volcano. The Ministry of Education and Culture has just established and implemented a special disaster prevention education curriculum at all school levels since the 2011-2012 academic year

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