Sumatra Journal of Disaster, Geography and Geography Education, December, 2019, Vol. 3, No. 2, pp. 196-201
DISASTER, GEOGRAPHY, GEOGRAPHY EDUCATION http://sjdgge.ppj.unp.ac.id/index.php/Sjdgge
ISSN : 2580 - 4030 (Print) 2580 - 1775 (Online), Indonesia

DISASTER MITIGATION OF MOUNT SINABUNG IN KARO DISTRICT, NORTH SUMATERA PROVINCE

* Eri Balian[1], Indang Dewata[1], Iswandi Umar[2], Bustari Muchtar[1], and Syafri Anwar[2]

*[1]Postgraduate Program, Universitas Negeri Padang, Indonesia
[2]Departement of Geography, Faculty of Social Sciences, Universitas Negeri Padang, Indonesia
E mail: eri_barlian@yahoo.com

*Corresponding Author: Received: Nov 23, 2019; Revised: Dec 1, 2019; Accepted: Dec 8, 2019

ABSTRACT: The volcanic eruption of Mount Sinabung has caused the loss of human lives. Hence, for minimizing losses, disaster mitigation is needed. The purpose of this study is to determine the policy directives in mitigating volcanic eruptions of Mount Sinabung. The method to determine the volcano hazard area is the assessment method using geographic information system techniques. Indicators in determining the hazard level are slope, soil type, geology, landform, vegetation, and land use. As for determining the policy directive, this study used the AHP method. The results show that 45 percent of the area is a high risk of the volcano hazard area. From the research, the appropriate policy directive for mitigation is relocating the area further from the volcano.

Keywords: Danger, Volcanic Eruption, Mitigation, Policy Directive

1. INTRODUCTION

Law No. 24/2007 on Disaster Management issued by National Agency for Disaster Management (BNPB) in 2012 explains that disaster-prone is a geological, biological, hydrological, climatological, geographical, social, cultural, political, economic, and technological condition or characteristic of a region for a certain time decreasing the capability to prevent, mitigate, be prepared, and respond to any emergency caused by the region condition. To prevent or minimize the adverse effects of floods, we need to do mitigations [1] [2] [3].

National Agency for Disaster Management of North Sumatera Province recorded an increase in landslide disasters both from the frequency and the extent of the affected area from 2000 to 2017. To minimize the impact of landslide risk, determining the landslide-prone zone of Mount Sinabung area is one of the ways to do mitigation. Based on the physical characteristics, Mount Sinabung has a very vulnerable area for landslides. a) Morphologically, 55 percent of the mountain's surrounding area is relatively steep (<27%). b) Around 70% of the land use has changed to agriculture. c) Rainfall intensity is increasing in the upper watershed areas [4] [5] [6] [7].

Growth in the world's population is rapidly increasing every year. The rapid population growth has increased land needs, especially for residential and agricultural areas. Due to the limitations of the earth's surface to support the need for settlements, people made the use of land regardless of its actual use. Districts around Mount Sinabung have an average population growth rate of 1.3 percent per year. The population growth increases the need for land as residential and agricultural areas. Around Mount Sinabung, the land characteristics have many limiting factors if we use it for residential and agricultural. The factors include a) relatively steep morphology, b) around 70 percent of the area is a forest area, and c) prone to landslides and volcanic eruptions [8] [9] [10] [11].

2. METHODS

Mount Sinabung is in the Karo Regency of North Sumatra Province. Administratively, eleven subdistricts surround the mountain have the risk of the volcano hazard. The three regions with the worst impacts are Namanteran, Tiganderket, and Payung. The research location is illustrated in Figure 1

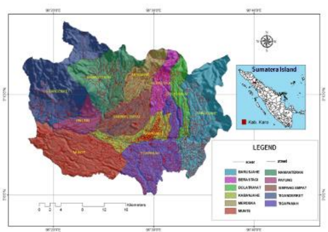

Fig 1. Research location

Sumatra Journal of Disaster, Geography and Geography Education, December, 2019, Vol. 3, No. 2, pp. 196-201
DISASTER, GEOGRAPHY, GEOGRAPHY EDUCATION http://sjdgge.ppj.unp.ac.id/index.php/Sjdgge
ISSN : 2580 - 4030 (Print) 2580 - 1775 (Online), Indonesia

Most of the areas based on the slope are rather steep and steep areas. Based [12] [13].there are four types of soil. They are entisol, inceptisol, oxisol, and ultisol. Most of the land has ultisol soil. The ultisol soil type has a rather thick layer of soil solum around 90-180 cm with clear boundaries between horizons. This soil varies in color from reddish to yellow or yellowish tones. The B horizon structure is blocky. The texture is from sandy clay to loamy clay, but most are clayey clay. Consistency of the topsoil is loose and firm in the subsoil.

On the slopes of Mount Sinabung, other than Ultisol soil, there is also inceptisol soil. Inceptisols are young geomorphic soil. They are more developed than Entisol. The word Inceptisol comes from the word Inceptum which means beginning. Generally, they have a cambic subsurface horizon. This type of soil has not yet developed further, so most of this land is quite fertile. In the Indonesian classification system, this soil includes Alluvial, Andosol, Regosol, Glei Humus soils. Several factors influence the formation of Inceptisol; 1) a highly resistant parent material; 2) position in an extreme landscape such as a steep area or valley; and 3) young geomorphological surface so that soil formation is not yet advanced.

Landslide-prone zones of Mount Sinabung in Karo District are determined using the geographic information system approach, which is the overlay method. Overlay analysis is using Art GIS 10.1 software. In determining the level of the Landslide susceptibility, this study uses six indicators: soil type, sloppiness, geological type, geomorphological process, rainfall, and land use (Table 1). Each indicator is divided further into several sub-indicators with different values.

Table 1. Landslides Risk Indicator

Indicator (value)	Sub-Indicator		Degree
Soil Type (0,1)	Andosol		1
	Latosol		2
	Podsolik		3
Sloppiness (0,25)	0-8 percent	Flat	1
	8-14 percent	Ramps	2
	15-25 percent	A bit steep	3
	25-40 percent	Steep	4
	> 40 percent	Very Steep	5
	Denudational		2
Geomorphological Process (0,1)	Fluvial		1
	Karst		2
	Volcanic		4
Geological Type (0,1)	Alluvial Soil		1
	Volcanic Rock		3
	Intrusive Rock		3
	Metamorphic rocks		3
	Limestone		2
	Brani Formation		3
	Kuantan Formation		3
	Ombilin Formation		3
	Sangkarewang Formation		3
	Tuhur Formation		
Rainfall Intensity (mm/year) (0,2)	2500-3000		1
	3000-3500		2
	3500-4000		3
	4000-4500		4
	4500-5000		5
	> 5000		6
Land Use(0,05)	Forest		1
	Plantation		2
	Settlement		4
	Rice fields		3
	Field		2
	Moor		3

Sources: [14] [15] [16] [17].

Sumatra Journal of Disaster, Geography and Geography Education, December, 2019, Vol. 3, No. 2, pp. 196-201
DISASTER, GEOGRAPHY, GEOGRAPHY EDUCATION http://sjdgge.ppj.unp.ac.id/index.php/Sjdgge
ISSN : 2580 - 4030 (Print) 2580 - 1775 (Online), Indonesia

The landslide-prone areas are determined using equation 1. The highest score of Landslide susceptibility is 4.1, and the lowest score is 1.1. The area is divided into three classes: high, medium, and low probability of landslide. Table 2 presents the class interval of landslide-prone areas.

$$KI = \frac{S_{max} - S_{min}}{k} \quad (1)$$

Where

KI : Class Interval
S_{max} : Maximum Score
S_{min} : Minimum Score
k : Number of Classes

Table 2. Class Interval of landslide-prone areas

Susceptibility Class	Class Interval	Susceptibility Index
Low Susceptibility	1,00-2,00	Low Susceptibility area
Medium Susceptibility	2,01-3,00	Medium Susceptibility area
High Susceptibility	3,01-4,01	High Susceptibility area

To determine the policy directives, we use the Interpretative Structural Modeling (ISM) method. The ISM method is a group assessment process through the structural model produced, to portray the complex matter of a system with carefully designed patterns using graphics and sentences [18]. The ISM method is quite effective at structuring complex issues because it can be used to define and clarify issues, assess impacts, and identify relationships between the policies.

The basic principle of the methodology is the identification of a structure within a highly beneficial system to form it effectively for better decision making. The ISM technique includes developing a hierarchy and classifying sub-elements [16][17][18][19].

In general, the stages of the ISM method are as follows:

1) Classifying each element into several sub-elements
2) Determining contextual relationships between sub-elements. Experts' opinion is needed to compare whether contextual relations exist or not to make a pairwise comparison of each element.
3) Arranging Structural Self Interaction Matrix (SSIM) by using V, A, X, and O symbols.
4) Making a Reachability Matrix (RM) table by replacing V, A, X, and O symbols with numbers 1 or 0.
5) Doing calculations based on transitivity rules, to adjust the SSIM matrix until we get a closed matrix.
6) Determining the sub-element of each element based on vertical or horizontal levels.
7) Compiling the Driver Power Dependence (DPD) matrix for each sub-element. The elements are classified into four quadrants:
   a. Quadrant I: Autonomous. Consists of sub-elements that have a driver power value (DP) ≤ 0.5 X and a dependent value (D) ≤ 0.5 X, where X is the number of sub-elements on each element. Sub elements in quadrant I are generally not related or slightly related to the system.
   b. Quadrant II: Dependent. Consists of sub-elements with driver power (DP) ≤ 0.5 X and dependent (D) ≥ 0.5 X, where X is the number of sub-elements on each element. Sub elements in quadrant II are dependent on elements in quadrant III.
   c. Quadrant III: Linkage. Consists of sub-elements that have a power driver value (DP) ≥ 0.5 X and a dependence value (D) ≥ 0.5 X, where X is the number of sub-elements on each element. Sub elements in quadrant III need to be carefully studied because every action on one sub-element will affect other sub-elements in quadrants II and IV.
   d. Quadrant IV: Independent. Consists of sub-elements with driver power value (DP) ≥ 0.5 X and a dependent value (D) ≤ 0.5 X, where X is the number of sub-elements on each element.

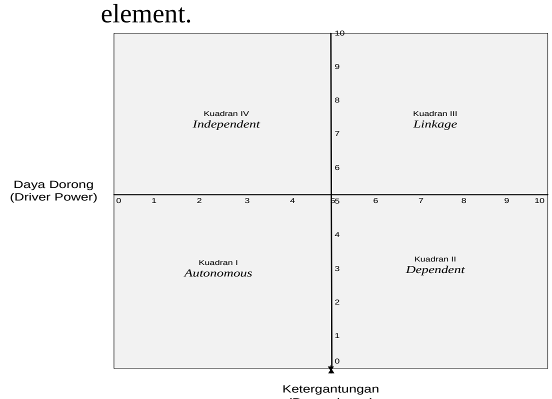

Figure 2. Power Driver and Dependent Matrix on ISM

3. RESEARCH RESULT

Three villages around Mount Sibanung area have a high susceptibility of Mount Sinabung eruption, namely Namanteran, Tiganderket, and Payung. In Figure 3, we can see that the impact of the eruption of

Sumatra Journal of Disaster, Geography and Geography Education, December, 2019, Vol. 3, No. 2, pp. 196-201
DISASTER, GEOGRAPHY, GEOGRAPHY EDUCATION http://sjdgge.ppj.unp.ac.id/index.php/Sjdgge
ISSN : 2580 - 4030 (Print) 2580 - 1775 (Online), Indonesia

Mount Sinabung is mostly on the area of plantations and mixed gardens. The sediments of volcanic ash carried by the river flow and these deposits have an impact on rice agriculture and community fisheries.

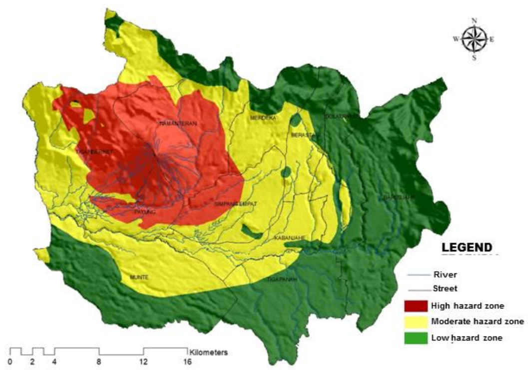

Figure 3. Map of the eruption hazard zone of Mount Sinabung

Figure 4 presents the eruption hazard zone of Mount Sinabung. Based on the analysis, three villages have a high level of danger, namely: Namanteran, Tiganderket, and Payung. Furthermore, the impact of the Mount Sinabung eruption was mostly on mixed plantation and plantation areas. Sedimentation from volcanic ash is carried by the river flow. These deposits have an impact on rice fields and community fisheries.

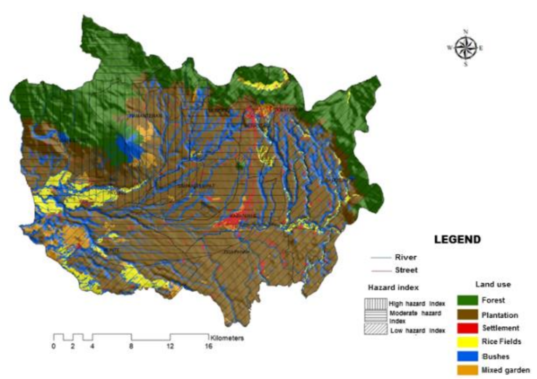

Figure 4. Overlay of the volcanic eruptions hazard with land use

Determining policy directives using the ISM method Expert opinions are needed through an FGD (Focus Group Discussion). The experts involved in the FGD came from various scientific fields and related institutions. In the FGD, eight sub-elements are taken as the policy directives in the mitigation of Sinabung volcano eruption disaster:

E1. Exploring and encouraging alternative income for the community in relocation areas
E2. Preparing for participatory area utilization in the slope area
E3. Cooperating and synergizing between institutions in spatial planning
E4. Compiling regulations and penalties for improper land use
E5. Maintaining information and disseminating alert on eruption Hazard risk areas
E6. Keeping the consistency of law enforcement for improper land use
E7. Doing thorough conservation and reforestation on the volcano slope area
E8. Disseminating and consistently implementing the spatial plans

Table 3. Structural Self Interaction Matrix (SSIM) of the final policy directives on Sinabung volcano disaster mitigation

NO	E1	E2	E3	E4	E5	E6	E7	E8
E1		X	A	A	X	A	A	X
E2			A	A	X	A	A	X
E3				X	V	V	V	V
E4					V	V	V	V
E5						A	A	X
E6							X	V
E7								V
E8								

Sources : ISM Analysis (2018)

Table 3 is the Structural Self Interaction Matrix (SSIM) of the final policy directives on Sinabung volcano disaster mitigation obtained from a combination of experts' opinions. The experts' opinions in the ISM analysis is in symbols or indexes of importance value. Then, the symbols are transformed into numbers, and this stage is called the Reachability Matrix (RM). Table 4 presents the Reachability Matrix (RM) of expert opinion. Table 4 presents the final Reachability Matrix (RM) in the policy directives of the Sinabung volcano eruption disaster mitigation in Karo District. In the table, the highest value of driver power (DP) is on sub-element E3 (Cooperating and synergizing between institutions in spatial planning) and sub-element E4 (Compiling regulations and penalties for improper land use). However, both sub-elements have the lowest dependence (D) on other sub-elements.

Figure 5 displays the relation between Driver power and dependency. The DP and D association is divided into four categories: autonomous, dependent, linkage, and independent. Sub elements contained in the independent quadrant are sub-elements with a high value of driver power with a great influence on the success of a program or activity plan. Besides, the sub-elements in the independent quadrant have the lowest level of dependence compared to the other sub-elements.

Sumatra Journal of Disaster, Geography and Geography Education, December, 2019, Vol. 3, No. 2, pp. 196-201
DISASTER, GEOGRAPHY, GEOGRAPHY EDUCATION http://sjdgge.ppj.unp.ac.id/index.php/Sjdgge
ISSN : 2580 - 4030 (Print) 2580 - 1775 (Online), Indonesia

Table 4 Reachability Matrix (RM) of the final policy directives of Mount Sinabung disaster mitigation

NO	E1	E2	E3	E4	E5	E6	E7	E8	DP	R
E1	1	1	0	0	1	0	0	1	4	3
E2	1	1	0	0	1	0	0	1	4	3
E3	1	1	1	1	1	1	1	1	8	1
E4	1	1	1	1	1	1	1	1	8	1
E5	1	1	0	0	1	0	0	1	4	3
E6	1	1	0	0	1	1	1	1	6	2
E7	1	1	0	0	1	1	1	1	6	2
E8	1	1	0	0	1	0	0	1	4	3
D	8	8	2	2	8	4	4	8		
L	1	1	3	3	1	2	2	1		

Source : ISM Analysis (2019)

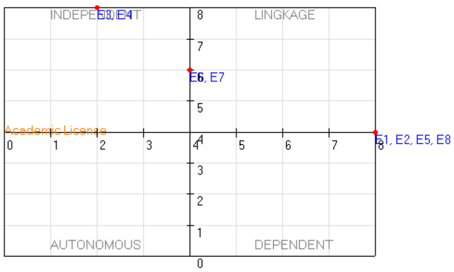

Figure 5. Graph of the relationship between driver power and dependence on the policy directives of the Sinabung eruption disaster mitigation

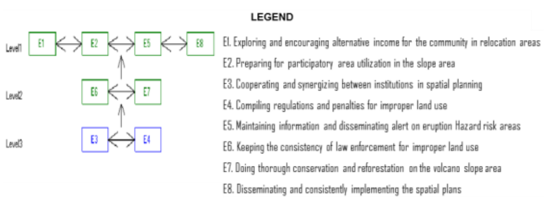

Figure 6. Hierarchical structure in the policy directives of the Sinabung volcano disaster mitigation

Figure 6 is the hierarchical structure of the policy directives of the Sinabung volcano eruption disaster mitigation in Karo District. In the picture, there are three levels of policy direction. At level 3, E3 and E4 sub-elements serve as the main policy directives. Furthermore, the policy directives on development on mitigation are sub-elements E6 and E7, and the final policy directives with four sub-elements: E1, E2, E5, and E8.

4. CONCLUSION

Based on the analysis results, three villages around Mount Sibanung area have a high Susceptibility of eruption hazard, namely Namanteran, Tiganderket, and Payung. The impact of the eruption of Mt. Sinabung was mostly in the plantations and mixed garden areas. The sediments from volcanic ash flow through the river. These sedimentations impacted rice agriculture and community fisheries. The policy directives of the Sinabung volcano eruption mitigation in Karo Regency is sub-element E3 (Cooperation and synergy between institutions), and sub-element E4 (Preparation of regulations and penalties). Both of the sub-elements have a high drive power, but both sub-elements have the lowest dependence (D) on other sub-elements.

5. REFERENCES

[1][BNPB] Badan Nasional Penanggulangan Bencana. Tentang Pedoman Umum Pengkajian Risiko Bencana Nomor 2 Tahun 2012.

[2] [BPBD] Badan Penanggulangan Bencana Daerah Karo. Statistik Bencana Daerah. 2018.

[3] [BPS] Badan Pusat Statistik Karo. Karo dalam Angka. 2018.

[4] Buol, S.W., F.D. Hole., and R.J. Cracken.. Soil Genesis and Classification. Second Edition. The Iowa State University Press. Amess. 1980

[5] Canuti, P., N.Casagli, and R. Fanti. Landslide Hazard for Archaeological Heritage: The Case of Tharros in Italy. Landslides News. 14/15: 40-43. 2003.

[6] Harun, U.R. Dinamika Penggunaan Sumberdaya Lahan di Jawa Barat 1970-1990. Jurnal PWK. 3: 48-53. 1992.

[7] Kustiawan, I. Permasalahan Konversi Lahan Pertanian dan Implikasinya terhadap Penataan Ruang Wilayah. Studi Kasus: Wilayah Pantura Jawa Barat. Jurnal PWK. 8: 49-60. 1997.

[8] Muta'ali, L., Daya Dukung Lingkungan untuk Perencanaan Pengembangan Wilayah. Badan Penerbit Fakultas Geografi (BPFG) Universitas Gadjah Mada.Yogyakarta. 2012.

[9] Martono, D.N., Surlan, dan B.T. Sukmana. Aplikasi Data Penginderaan Jauh untuk Mendukung Perencanaan Tata Ruang di Indonesia. http://io.ppi.jepang.org/article. 2005.

[10] Pribadi, D.O., D. Shiddiq, dan M. Ermyanila. Model Perubahan Tutupan Lahan dan Faktor-Faktor yang Mempengaruhinya. Jurnal Teknologi Lingkungan. Pusat Pengkajian dan Penerapan Teknologi Lingkungan. 7: 35-51. 2006.

[11] [RI] Republik Indonesia. 2007. Undang-undang Republik Indonesia Nomor 24 Tahun 2007 tentang Penanggulangan Bencana.

[12] Sadyohutomo, M. Manajemen Kota dan Wilayah Realitas dan Tantangan. Penerbit Bumi Aksara. Jakarta. 2008.

[13] Sitorus, S.R.P. Pengembangan Lahan Berpenutupan Tetap sebagai Kontrol terhadap Faktor Resiko Erosi dan Bencana Longsor. Makalah. Lokakarya Penataan Ruang sebagai Wahana untuk Meminimalkan Potensi Kejadian Bencana Longsor. Jakarta. 7 Maret 2006

[14] Syahrin, A. Pengaturan Hukum dan Kebijakan Pembangunan Perumahan dan Permukiman Berkelanjutan. Pustaka Bangsa Press. 2003.

[15] Suryani, R.L. dan A. Marisa. Aspek-Aspek yang Mempengaruhi Masalah Permukiman di Perkotaan. Program Studi Arsitektur. Fakultas Teknik USU. Medan. 2005.

[16] Umar, I., Widiatmaka, Pramudya, B., dan Barus, B., Evaluasi Kesesuaian Lahan untuk Permukiman dengan Pendekatan MCE di Kota Padang. Jurnal PSL. 2 (2): 84-95. 2017.

[17] Utoyo, B.S., E. Anwar, I.M. Sandy, R.S. Saefulhakim, dan H. Santoso. Analisis Keterkaitan antara Pertumbuhan Wilayah dengan Pola Perubahan Struktur Penggunaan Lahan. Forum Pascsarjana. 24: 159-162. 2001.

[18] Virdin J.W. Understanding the Synergies between Climate Change and Desertification. UNDP. 2001.

[19] Zain, A.F.M. Distribution, Structure dan Function of Urban Green Space in Southeast Asian Mega-Cities with Special Reference to Jakarta Metropolitan Region (JABOTABEK). Doctoral Degree Program. Department of Agricultural and Environmental Biology Graduate School of Agricultural and Life Sciences. The University of Tokyo. Japan. 2002.