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RESEARCH ARTICLE

Landslide Risk Analysis in Kelud Volcano, East Java, Indonesia

Syamsul Bachri*, Sumarmi, Listyo Yudha Irawan, Sugeng Utaya, Lela Wahyu Ning Tyas, Farizki Dwitri Nurdiansyah, Alif Erfika Nurjanah, Rahmat Wirawan, Akhmad Amri Adillah and Denny Setia Purnama
[1]Department of Geography, State University of Malang, Jl. Semarang 05, Malang 65145, Indonesia

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Correspondent email:
sardi@ung.ac.id

Abstract Pandansari village became one of the villages that has frequent landslide events in the period 2009-2015 compared with the surrounding area in Malang regency. The purpose of this study was to determine the level of landslide risk located within an active volcano. To enhance the comprehensive analysis of landslide disasters, we used a risk concept in this study. The landslide risk analysis was based on 3 determinants, namely hazards, community vulnerability, and regional capacity. The data collections were conducted using observation and documentation for landslide hazards and interviews as well as Focus Group Discussion (FGD) for vulnerability and capacity aspects. The interviewed were applied for community and local government of Pandansari village. The recorded interviews were transcribed and analyzed according to recurrent themes in the answers. Findings from field investigation were then confronted with previous existing concepts of human exposure to natural hazards. Furthermore, the landslide hazard data were analyzed using spatial analysis tools, including GIS scoring, weighting, and overlaying weighted sum. The results showed the level of landslide risk has different values depending on the risk parameter, community vulnerability, and regional capacity. The level of landslide risk was divided into three levels, namely high with an area of 557.71 ha, moderate with 774.49 ha, and low with 1118.77 ha. Each of the risk factors, vulnerability, and capacity, has its characteristics in influencing the landslide risk in Pandansari Village. In relation to landslide disaster management, the risk analysis gives comprehensive input reaching good management practice in Pandansari village.

1.Introduction

Indonesia is a country with the highest number of volcanoes in the world, namely 129 active volcanoes or around 15% of all volcanoes worldwide (Abidin et. al., 20017). One of the active volcanoes in Indonesia is Kelud Volcano in East Java Province. Administratively, it is located in 3 regencies: Blitar, Kediri, and Malang. The last increase in Kelud Volcano eruption activity occurred on February 14, 2014, which produced volcanic material of >200 x 10^6 m^3 (Blake & GNS Science., 2015).

The amount of eruption material of a volcano may trigger other disasters (Nurdiansyah, 2017). The eruption of Kelud Volcano has a direct and indirect impact on the physical, social, and economic conditions of the surrounding community (Bachri, 2017). One of the secondary hazards (continued) that might follow the volcano eruption is a landslide disaster (Huppert & Dade, 1998; Keys, 1998).

A landslide is one of the geological hazards that may cause injury, loss of life, and loss to the community. Landslides are defined as the movement of soil, rocks, and organic matter, that follows the direction of gravity (Nadim et al. 2006; Highland & Bobrowsky, 2008), which are controlled by geomorphological and geological factors (Van Westen et al., 2011) and may be triggered by various control factors, such as rainfall, earthquakes, volcanic activity, changes in groundwater, and anthropogenic activity (Ermini et al., 2005; Catani et al., 2005; Ercanoglu, 2002; Highland & Bobrowsky, 2008).

Ngantang District in Malang Regency has a relatively higher frequency of landslides when compared with other districts in Malang Regency (Profile Book of Malang Regency BPBD in Ahdi (2015).

Pandansari Village in Ngantang District was the worst affected village of the Kelud Volcano eruption in 2014, especially due to the sand and volcanic ash fall (Wardhana, Garri Martha Kusuma, 2014; Lestari, et.al., 2014). Pandansari village was one of the villages that have the potential for landslides. Almost all hamlets in Pandansari Village have a land carrying capacity condition and slopes of more than 45 °, this caused the area to be prone to landslides. The magnitude of the potential/likelihood of a landslide disaster has given rise to the need to make a comprehensive effort on disaster risk through an analysis of landslides risk in this region to minimize the impact of losses from the disaster (Chiu., 2015). Since the direction of landslide disaster is currently more in technical part (viz. mapping), this research try to make a comprehensive study to capture landslide hazards in Pandasari village through risk concept analysis. Three-component such as hazard, vulnerability, and capacity analysis were applied in this study.

This research is located in Pandansari Village, which is one of the very impacted areas because of the Mount Kelud eruption in February 2014. Administratively Pandansari Village is part of Ngantang District, Malang Regency, East Java. Pandansari Village consists of seven “Dusun”, namely

Plumbang, Bales, Munjung, Sambirejo/ Kutut, Wonorejo/ Pait, and Sedawun, and one land ownership managed by Perhutani (Fig. 1).

Pandansari Village is located in “Kawasan Rawan Bencana” (KRB) 2 and 1, which approximately has a radius from Mount Kelud between 6-7 kilometers. In February 2014 because of Mount Kelud Eruption, this event caused enormous damage to settlement, public facilities, and agricultural land. Figure 2 shows that many houses were severely damaged because of material that ejected from Mount Kelud Eruption.

The material ejected from Mount Kelud eruption in 2014 reached more than 200 x 10^6 m^3 (Bachri et al, 2019). According to Balitkabi Litbang Pertanian, the thickness of material eruption that covered the Pandansari Village area reached between 25 – 40 centimeters. Because of the huge of material from Mount Kelud eruption that covered Pandansari Village, it will trigger another geophysical hazard, especially landslide. . In the future, eruption material that covers the entire area of Pandansari Village will be a source of landslide material. Therefore, the research related to landslide risk assessment is important to carry out because it will be the basis for disaster risk reduction.

Table 1. Disaster Prone Areas in Malang Regency

Natural Disasters	Regional
Landslide	Ngantang, Kasembon, Pujon, Dampit, Tirtoyudo, Ampelgading, Donomulya, Wajak, Poncokusumo, Jabung
Flood	Singosari, Tirtoyudo, Dampit, Sumawe, Bantur, Amplegading
Drought	Kalipare, Pagak, Sumawe, Singosari, Poncokusumo, Donomulyo,Sumberpucung, Bantur, Gedangan
Tsunami	Donomulyo, Bantur, Gedangan, Sumawe, Tirtoyudo, Ampelgading
Storm	Malang Regency
Volcano	Kasembon, Ngantang, Poncokusumo, Wajak, Dampit, Tirtoyudo, Ampelgading,Karangploso, Singosari, Lawang, Jabung

Source : Profile Book of Malang Regency BPBD in Ahdi (2015).

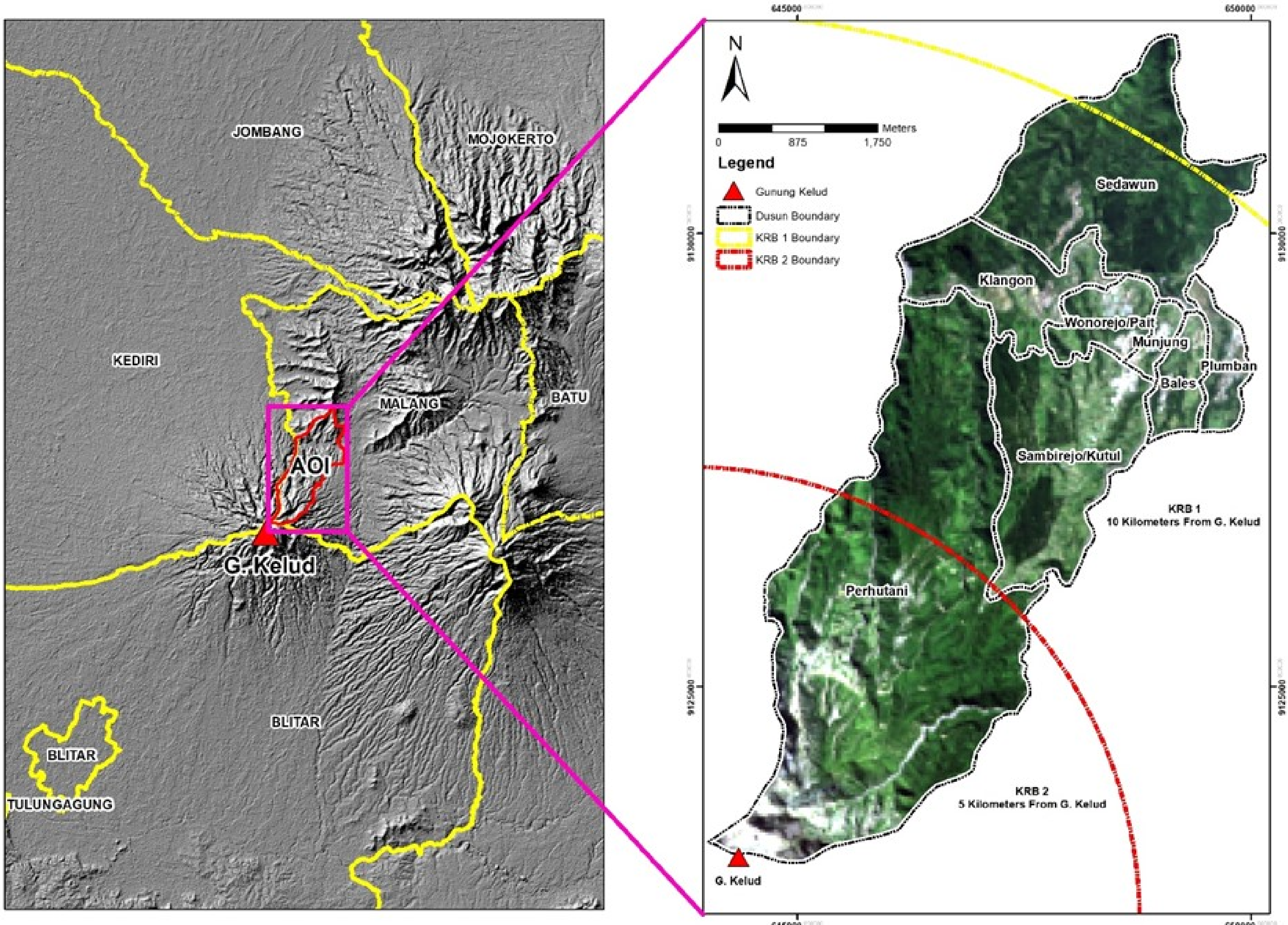

Figure 1. Pandansari Village, Ngantang District for This Study Area

Table 1. Disaster Prone Areas in Malang Regency

Natural Disasters	Regional
Landslide	Ngantang, Kasembon, Pujon, Dampit, Tirtoyudo, Ampelgading, Donomulya, Wajak, Poncokusumo, Jabung
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Tsunami	Donomulyo, Bantur, Gedangan, Sumawe, Tirtoyudo, Ampelgading
Storm	Malang Regency
Volcano	Kasembon, Ngantang, Poncokusumo, Wajak, Dampit, Tirtoyudo, Ampelgading,Karangploso, Singosari, Lawang, Jabung

Figure 2. The Damage to Settlement in Pandansari Village After Mount Kelud Eruption in 2014
(Image by Balitkabi Litbang Pertanian)

The material ejected from Mount Kelud eruption in 2014 reached more than 200 x 10^6 m^3 (Bachri et al, 2019). According to Balitkabi Litbang Pertanian, the thickness of material eruption that covered the Pandansari Village area reached between 25 – 40 centimeters. Because of the huge of material from Mount Kelud eruption that covered Pandansari Village, it will trigger another geophysical hazard, especially landslide. . In the future, eruption material that covers the entire area of Pandansari Village will be a source of landslide material. Therefore, the research related to landslide risk assessment is important to carry out because it will be the basis for disaster risk reduction.

2. Methods

This study referred to two data collection processes, namely primary and secondary. Primary data collection was carried out through field observations, interviews, and Focus Group Discussions (FGD) to determine the level of hazard and capacity of the area in Pandansari Village in facing the landslides disaster. Whereas, secondary data was in the form of data collected from legislation, books, websites, and journals that are relevant to determine the level of vulnerability of the community in Pandansari Village, Ngantang District.

Factors that play a role in determining hazards and assessing disaster risks in the study area are the threat/danger factors, community vulnerability factors, and regional capacity factors (vig. Tabel 2). Hazard factor assessment is an important part of disaster risk analysis (Ayala., 2001, (Fell et al., 2008, Van Westen et al., 2008),).

The assessment of the hazard factor in this study was arranged based on the parameters that caused landslides to occur based on the research conducted by Nurdiansyah (2017) using the Fuzzy-AHP method. The community vulnerability factor was based on the Regulation of the Head of the National Disaster Management Agency No. 02 of 201, covering physical, social, economic, and environmental parameters.

The factor of capacity/capability of the region was prepared based on the Regulation of the Head of the National Disaster Management Agency Number 03 of 2012, covering the rules and institutions of disaster management; early warning and disaster risk assessment; disaster education; reduction of basic risk factors; and development of preparedness on all lines.

The classification of landslide risk level in Pandansari Village, Ngantang District was divided into 3 classes, namely high, moderate, and low, see Table 3.

Table 2. Research Variables and Weighting Class

Variables	Sub-Variables	Parameters		Weight (%)	Low	Moderate	High
HAZARDS	Hydrology characteristic	- *Topographic Wetness Index*/TWI		6,53	Secondary Data (Nurdiansyah,2017) by modification		
		- *Stream Power Index*/SPI		19,34			
		- *Rainfall*		23,81			
	Lithology characteristic	- Soil Texture		5,87			
		- COLE value		0,56			
	Topography characteristic	- Slope		18,45			
		- *Topographic Position Index*/TPI		10,19			
		- Land Height		14,69			
	Land use			0,56			
COMMUNITY VULNERABILITY	Physical (40%)	- Building Vulnerability (house)	Total Building (house)	40	<500 units	500-1000 units	>1000 units
		- Public Facility Vulnerability	TK, SD, SMP/MTS, SMA/MAN/SMK, Posyandu, Polindes, Health Center, Mosque, Government Office	30	<10 units	10-30 units	>30 units
		- Vulnerability of critical facility unit	Electric Network, Road Network Ratio,	30	<10 units	10-30 units	>30 units
	Social (25%)	- Total Population		35	(<1.000) person	(1.000-2.500) person	(>2.500) person
		- Population Density,		35	(<50000) person	(500-1.000) person	(>1.000) person
		- Social Sensitivity and Vulnarable Groups	Age group ratio,	10	< 20 %	20-40 %	>40 %
			Sex Ratio	10	< 20 %	20-40 %	>40 %
			Diffable ratio,	10	< 20 %	20-40 %	>40 %
	Economic (25%)	- Productive Land		50	<50 million	50-200 million	>200 million
		- Total Livestock Ownership		50	<50 animals	50-200 animals	>200 animals
	Environmental (10%)	- Land Use Sector for Protected Forest Areas		90	<20 ha	20-50 ha	>50 ha
		- Land Use Sector for Shrub Areas		10	<10 ha	10-30 ha	>30 ha

Continue.....Table 2. Research Variables and Weighting Class

AREA CAPACITY	Rules and Disaster Management Institutions	- Policy Framework and Nasional/Local Legal		No	Yes, but doesn't work	Policy Framework and Nasional/Local Legal and work
		- Availability of Disaster Management Organization	20	No	Disaster Management Organizations such as BPBD, SAR, etc	Regional Disaster Management Organization and Local Disaster Management Organization
		- Participation and decentralization of the division of authority at the local level		No and doesn't work	Yes, but doesn't work	Yes and work
	Early Warning and Disaster Risk Assessment	- Jenis sistem peringatan dini *(Early Warning System)*		No	Simple	Modern
		- Regional disaster risk assessment documents and inter-regional cooperation for disaster risk reduction	20	No	Yes, but doesn't work	Yes
	Disaster Education	- Disaster information that can be accessed by all stakeholders		No	Yes, but can't be accessed	Yes
		- Disaster socialization	20	Never	Yes, but don't get that	Yes
	Reduction of Basic Risk Factors	- Disaster-resistant cultural practice strategies for the entire communities		No and doesn't work	Yes, but doesn't work	Yes and work
		- Types of evacuation routes		No	Simple	Modern
		- Evacuation guides		No	Simple	Modern
		- Types of evacuation location		No	Simple	Modern
		- Amount of health workers		<10 person	10-20 person	>20 person
		- Number of health facilities		<10 units	10-20 units	>20 units
		- Disaster anticipation efforts		Never	Yes, but doesn't work	Yes
		- Disaster Risk Reduction Policies on Natural Resources and land Use	20	No	Yes, but doesn't work	Yes and work
		- Disaster Risk Reduction Policies on Population factors		No	Yes, but doesn't work	Yes and work
		- Disaster Risk Reduction Policies on Economic		No	Yes, but doesn't work	Yes and work
		- Disaster Risk Reduction steps in the post-disaster rehabilitation and recovery process		No	Yes, but doesn't work	Yes and work
	Development of Preparedness on All Lines	- Aids Acquisition		No	Yes, but don't get that	Yes
		- Policies, Institutional technical capacity and mechanisms for handling emergency disaster	20	No	Yes, but doesn't work	Yes and work
		- Financial and logistical reserves and anticipatory mechanisms		No	Yes, but not enough sufficient	Yes and enough sufficient

Source: Compilation PerKa BNPB No.02 Year 2012; PerKa BNPB No.03 Year 2012; and previous research (Nurdiansyah, 2017)

Table 3. Landslide Hazard Level

Interval	Criteria	Class	Score
24-30	High Hazard Level	1	30
17-23	Moderate Hazard Level	2	20
10-16	Low Hazard Level	3	10

Source : Data Analysis, 2018

The total vulnerability score in Pandansari Village, Ngantang District, was calculated using the formula below:

Total Vulnerability =
{ 40 (social vulnerability) + 25 (physical vulnerability) + 25 (economic vulnerability) + 10 (environmental vulnerability) }

The classification of the total vulnerability level in Pandansari Village, Ngantang Subdistrict was divided into high, moderate, low as see Table 4.

The determination of the disaster capacity level in Pandansari Village, Ngantang District, was carried out using the following calculation:

Capacity Level =
{ 20 (disaster management rules and institutions) + 20 (early warning and disaster risk assessment) + 20 (disaster education) + 20 (basic risk factors reduction) + 20 (development of preparedness on all lines)}

The classification of the total capacity level of Pandansari Village in Ngantang District was divided into high, moderate, and low as see Table 5.

The data on landslide risk factors, community vulnerability, and area capacity were then analyzed using *Geographic Information System* (GIS) by utilizing the weighting technique, scoring, and overlay weighted sum as the determinant of the landslide risk level. The landslide risk disaster assessment could be done using the following approach:

$$\text{Disaster Risk} = \frac{\text{Hazard} \times \text{Vulnerability}}{\text{Capacity}}$$

Table 4. Total Vulnerability Level

Interval	Criteria	Class	Score
24-30	High Vulnerability Level	1	30
17-23	Moderate Vulnerability Level	2	20
10-16	Low Vulnerability Level	3	10

Source : Data Analysis, 2018

Table 5. Total Capacity Level

Interval	Criteria	Class	Score
24-30	High Capacity Level	1	30
17-23	Moderate Capacity Level	2	20
10-16	Low Capacity Level	3	10

Source: Data Analysis, 2018

The classification of landslide risk disaster in Pandansari Village, Ngantang District, was divided into three level of high, moderate, and low, by using interval class calculation as follows:

$$\text{Interval Class of Disaster Risk} = \frac{\text{Total High Score} - \text{Total Lowest Score}}{\text{Total Class}}$$

$$\text{Interval Class} = \frac{39{,}75 - 6{,}12}{3} = \frac{33{,}63}{3} = 11{,}21$$

Table 6. Classification of Landslide Risk Disaster

Interval	Criteria	Class	Score
24-30	High Level	1	30
17-23	Moderate Level	2	20
10-16	Low Level	3	10

Source: Data Analysis, 2018

The analysis process using GIS produced a low, moderate, and high level of zones in each factor. The following step was the process of visualizing data in the form of maps. The utilization of GIS technology was a standard tool for spatial production and presentation of disaster risk information. The research scheme carried out in this study can be seen in Figure 3.

3.Result and Discussion

Landslide Hazard Analysis

A hazard is a phenomenon carrying the potential to cause loss of life or injury, property damage, social and economic disturbances, or environmental degradation. This event has the possibility of occurring within a certain period, area, and intensity (UN-ISDR, 2004). Based on the results of the analysis, 3 categories of landslide hazards was identified in each hamlet and land ownership in Pandansari Village, Ngantang District, namely landslide hazard in the low category with an area of 56.22 ha, moderate category with an area of 638.11 ha, and high category with an area of 1768.92 ha. The mapping of landslide susceptibility/ hazard provides the basis for predicting landslide events in the form of landslide susceptibility/ hazard zoning.

The Distribution Landslide Analysis for Each Class Hazard Category

Low category of landslides hazards in Pandansari Village has an area of 56.22 ha or around 2.28% of the total study area. The hamlet with the most extensive low landslide hazard category was Klangon Hamlet with an area of 32.69 ha.

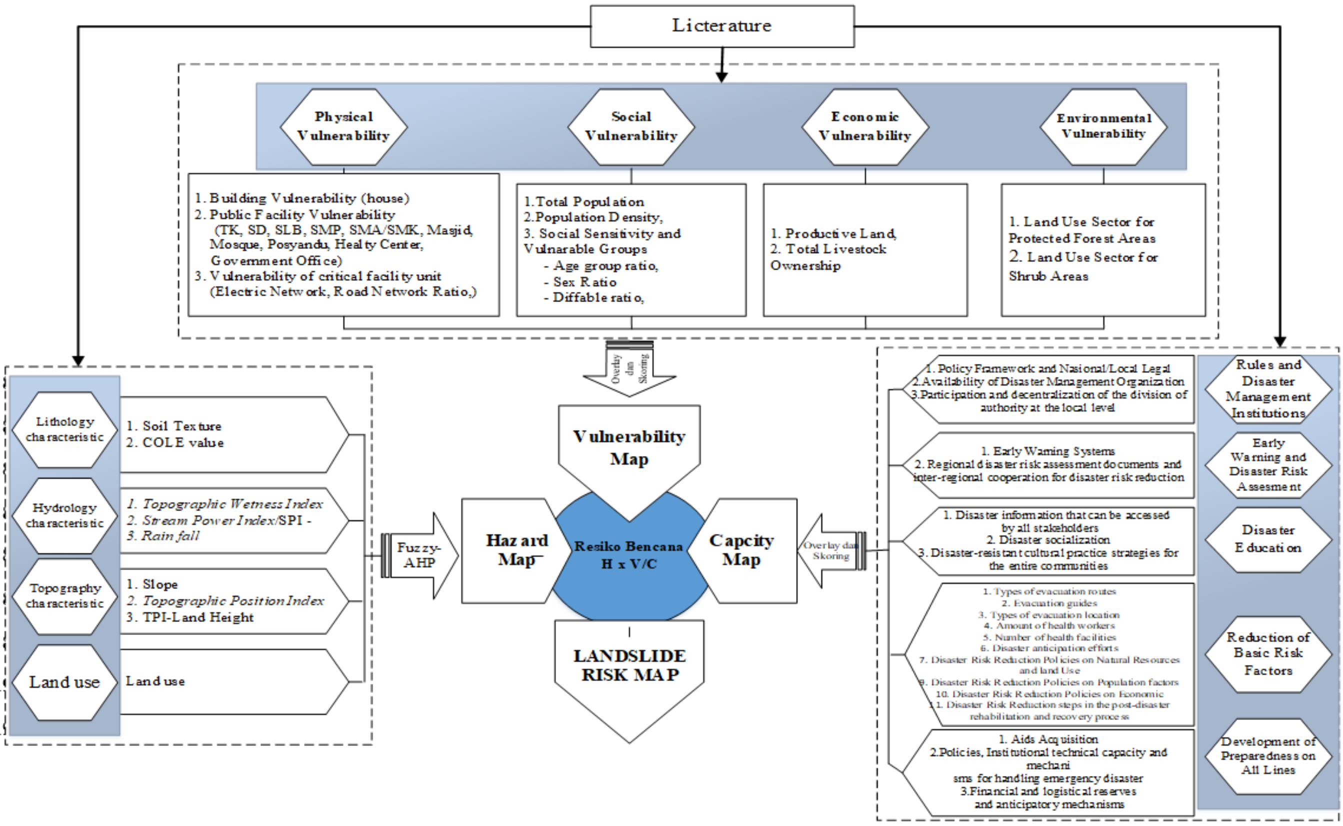

Figure 3. Work Flow the Research

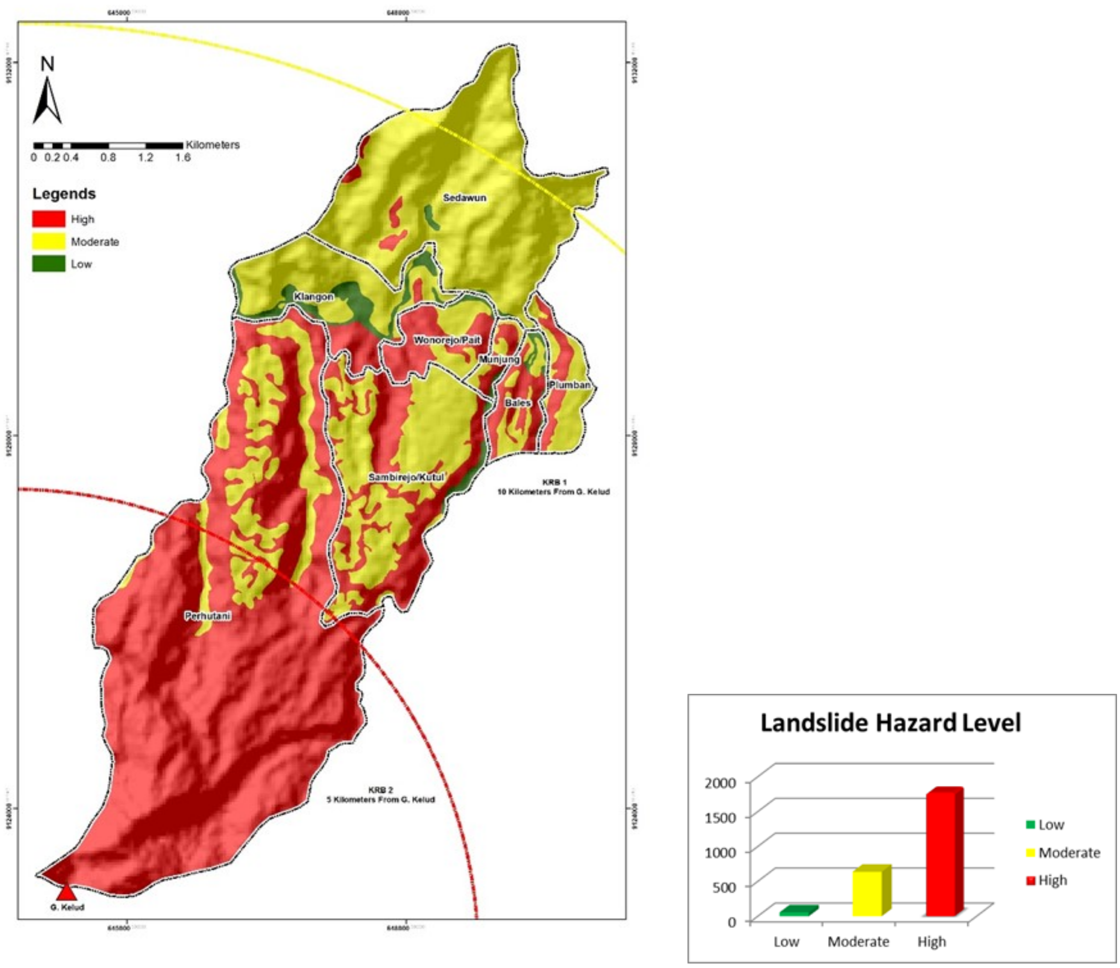

Figure 4. Maps and Diagrams of Landslide Hazard in Pandansari Village, Ngantang District

The land characteristics developed in this class were having a flat slope, tending to be around the watershed, and land use was dominated by rice fields. The moderate category of landslide hazard in Pandansari Village has an area of 638.11 ha or about 25.90% of the total study area. Based on figure 5, the hamlet which the widest landslide hazard class was Sambirejo Hamlet with an area of 176.05 ha. Land characteristics developed in this class were a sloping slope, andesite rock, volcanic breccias, tuff breccias, tuff and andesite deposits, regosol and lithosol, and land use in the form of rice fields and plantation.

The agricultural land use such as horticultural plantations and rice fields are areas that were most affected by the eruption of Mount Kelud in 2014. This area has a potential for landslides because the agricultural area in Pandansari Village is located in an area with a slope of more than 15%. The rice fields are not strong enough to bind the soil and cause the soil to be saturated with water, making it easy for landslides to occur (Karnawati, 2003). In figure 3 shows how the material eruption damaged to a horticultural plantation in Pandansari Village and shows the thickness of the material that covered this agriculture land use.

The high category of landslide hazard in Pandansari Village has an area of 1768.92 ha or about 71.81% of the total research area. The land belonging to Perhutani was the widest landslide hazard category compared to the others, with an area of 1124.74 ha.

Land characteristics developed in this class were steep to very steep slopes, sedimentary rocks, volcanic breccias, tuff, and andesite lava, regosol, reddish-brown lithosol, and latosol, and land use which are mostly forest and shrubs. Karnawati (2001) explained that slope topography is a very important factor in the process of landslides. Steep and steep slopes or cliffs may increase the driving force so that the landslide occurrences of a landslide are higher. This situation is influenced by the geomorphological conditions of the

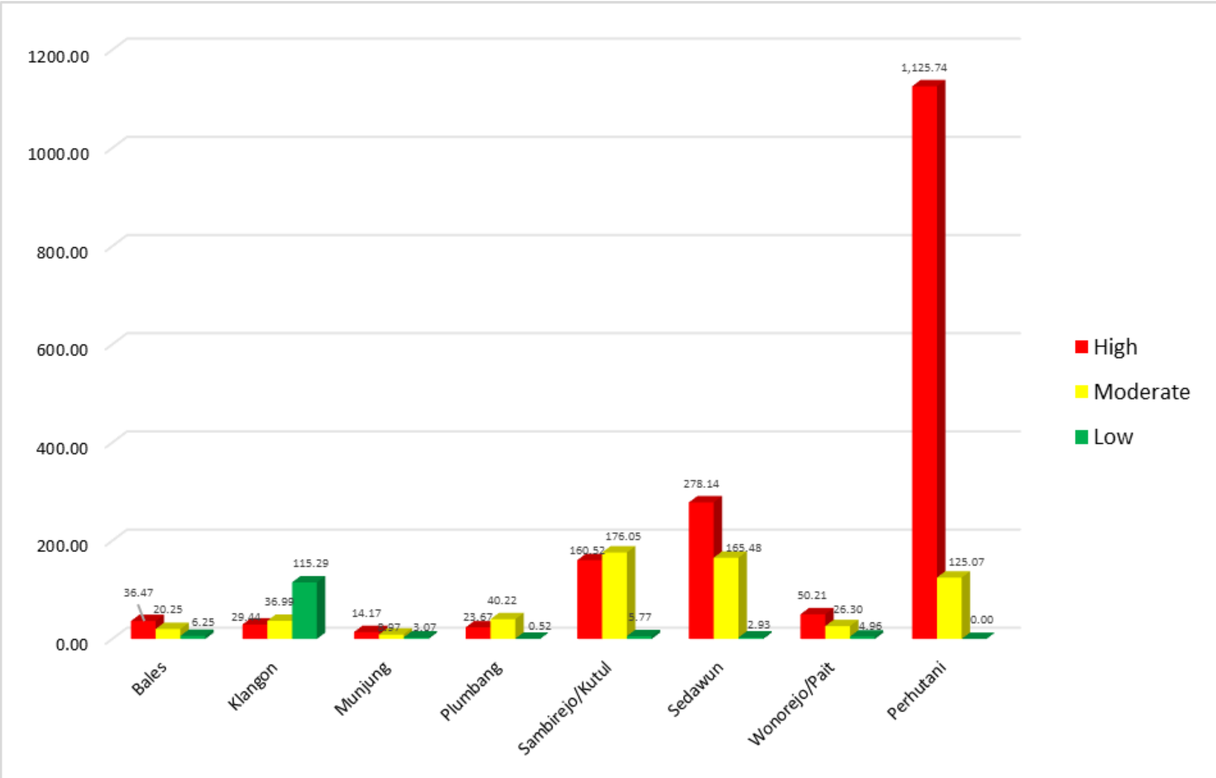

Figure 5. The Category of Landslide Hazard Diagram in Pandansari Village, Ngantang District

Figure 6. Horticultural Plantations (Tomato and Corn) Damaged by Mount Kelud Eruption in February 2014

research area, which is located in a volcanic region. In addition to the dominance of the middle slopes to the top of the volcano, the nature of the soil structure is dominated by the slickenside on the moderate slope triggering factor for landslides.

The degradation of land resources quality due to the increasingly complex demand for land tenure or land processing results in a decrease in land carrying capacity (Moniaga, 2011). A lot of types of human activities, ranging from land-use changes to the scarps construction without regard to the slope stability (Surono, 2003), further aggravate the environmental conditions that cause the possibility of a landslide hazard to increase.

Landslide distribution/inventory map has a role to detect, delineate, and describe the spatial distribution of areas with the potential for landslides (Guzzeti et al., 1990; Corominas, 2013) and understand changes in the appearance of the earth's surface and become the basis for the risk and vulnerability assessment of landslide hazard (Nurdiansyah, 2017).

The Vulnerability Aspect of Landslide Hazard

Vulnerability conditions in the study area are influenced by physical and socio-economic conditions (Westgate and O'Keefe, 1976; Maskey, 1993). In this research, we used the vulnerability factors, such as physical, social, economic and environmental vulnerabilities (UNPD, 2004; UN-ISDR, 2004; Blaikie et al., 1994; Pelling, 2003). The results of the parameters used in determining aspects of community vulnerability can be seen in some of the images see Figure 7.

Area Capacity Aspect

The area capacity factor in this study has been regulated in the Regulation of the Head of BNPB Number 03 year 2012, concerning the guidelines for assessing regional capacity in disaster management. Regional capacity aspects in implementing disaster management are important parameters for determining success for disaster risk reduction. The capacity data/regional capability related to the management of landslide disasters in Pandansari Village, Ngantang District, were acquired using interview methods and Focus Group Discussion (FGD). FGD activities are a means of obtaining information, opinions, and ideas from all participants on a topic that is accompanied by explanations (Krueger, 1988).

There were two classes of regional capacity in each hamlet and land ownership in Pandansari Village, Ngantang District, namely the high capacity class with an area of 1199.09 ha and the low capacity class with an area of 1258.88 ha. Factors influencing the high capacity class were the high level of rules and institutional parameters, early warning and disaster risk assessment, disaster education, and reduction of basic risk factors. While the preparedness development factor in all lines was in the medium level category.

Figure 7. Landslide Hazard in Pandansari Village, Ngantang District

The community capability in Pandansari Village to prepare themselves, to prevent and overcome disasters was done by completing infrastructure, regulations, completeness of the communication system, evacuation of health facilities, training, socialization, organizational completeness, the community capability to reduce, prevent and manage continuing disasters with related parties. This was in accordance with the statement (Anderson & Woodrow, 1989 in Paripurno 2001) that the resources, skills, knowledge, the ability of the community, organizational capabilities, and the attitude to act in this case are necessary to face disasters. Ideas and practices carried out by the community were the evidence of the communities capability to deal with disasters.

The Risk of Landslide Hazard in Pandansari Village, Ngantang District

One of the benefits of calculating disaster risk is as the material in formulating preparedness plans and strategic actions in disaster mitigation. In fact, risk analysis is an important aspect that needs to be considered in spatial

Table 7. Total Vulnerability Score in Pandansari Village

Land Ownership	Vulnerability Score					Total Vulnerability Level
	Physical	Social	Economic	Environmental	TOTAL	
Dusun Plumbang	20	20	30	10	22,4	Moderate
Dusun Bales	10	10	20	20	16,2	Moderate
Dusun Munjung	10	20	20	10	16,7	Moderate
Dusun Sambirejo	20	10	30	30	18,35	Moderate
Dusun Wonorejo	10	10	20	20	16,2	Moderate
Dusun Klangon	10	10	20	30	15,7	Low
Dusun Sedawun	20	10	20	30	17,1	Moderate
Perhutani	10	10	10	30	13,25	Low

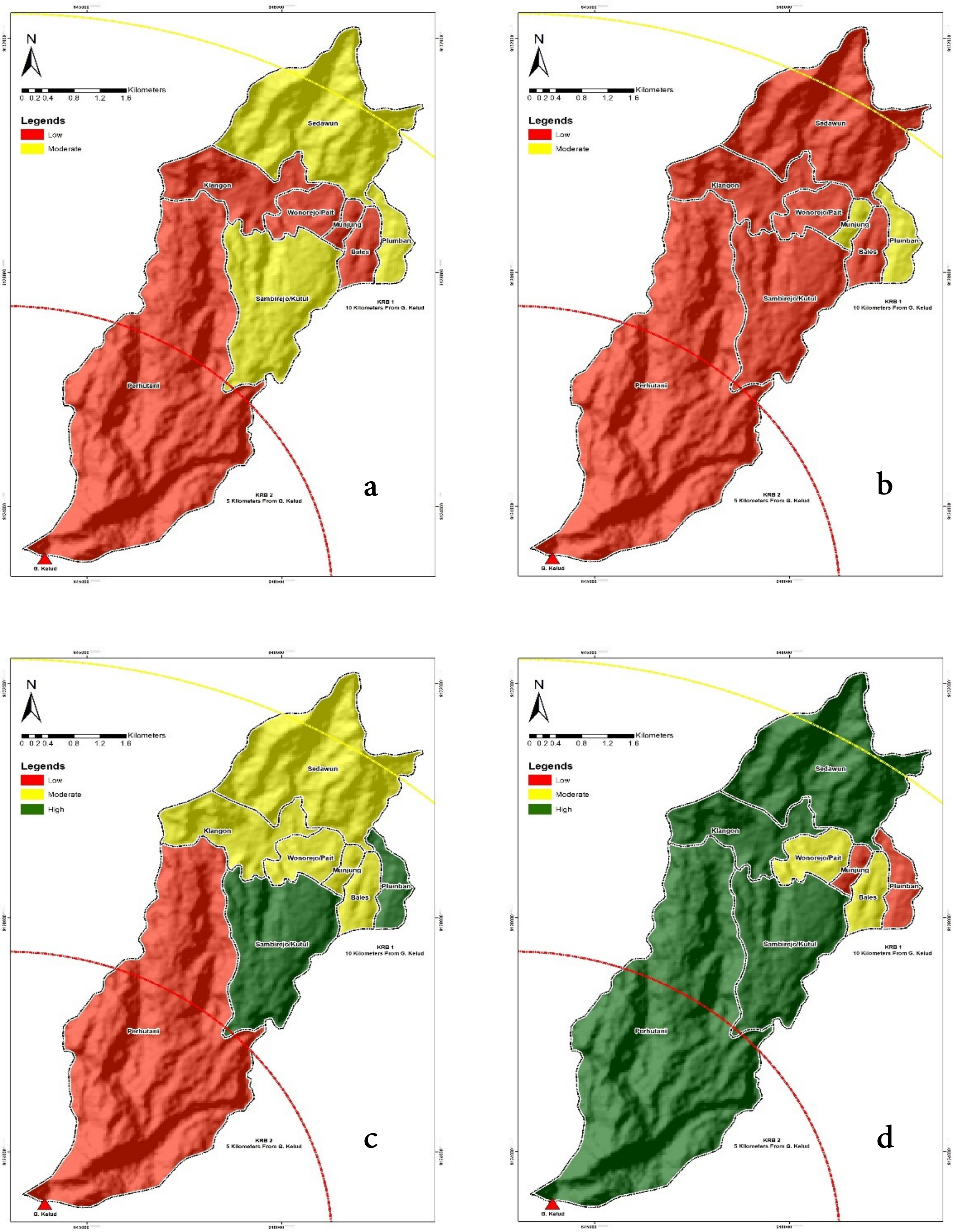

Figure 8. Determining Parameters of Vulnerability Level: a. Physical, b. Social, c. Economic, d. Environment.

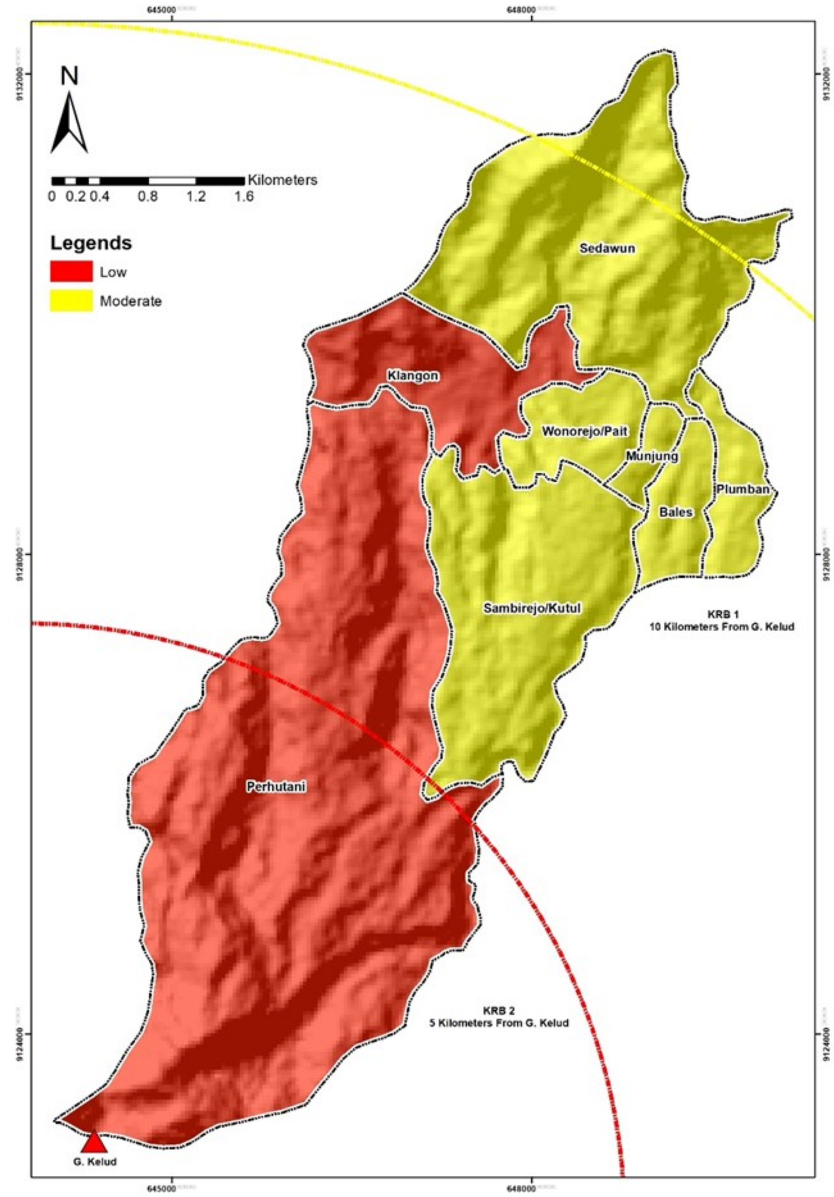

Figure 9. Maps and Diagrams of Vulnerability Level in Pandansari Village, Ngantang District

Figure 10. Focus Group Discussion (FGD) in Pandansari Village, Ngantang District

Table 8. Total Capacity Level in Pandansari Village, Ngantang District

Land Owner-ship	Capacity Score						Total Capacity Level
	Rules and Disaster Management Institutions	Early Warning a nd Disaster Risk Assessmen t	Disaster Education	Reduction of Basic Risk Factors	Development of Preparedness on All Lines	TOTAL	
Dusun Plumbang	26,66	30	30	26	20	26,53	High
Dusun Bales	26,66	25	30	24	26,66	26,46	High
Dusun Munjung	26,66	30	30	22	20	25,73	High
Dusun Sambirejo	26,66	25	26,66	23	20	24,26	High
Dusun Wonorejo	26,66	25	30	22	26,66	26,06	High
Dusun Klangon	26,66	30	30	24	13,33	24,8	High
Dusun Sedawun	26,66	30	30	24	26,66	27,46	High
Perhutani	10	10	10	10	10	10	Low

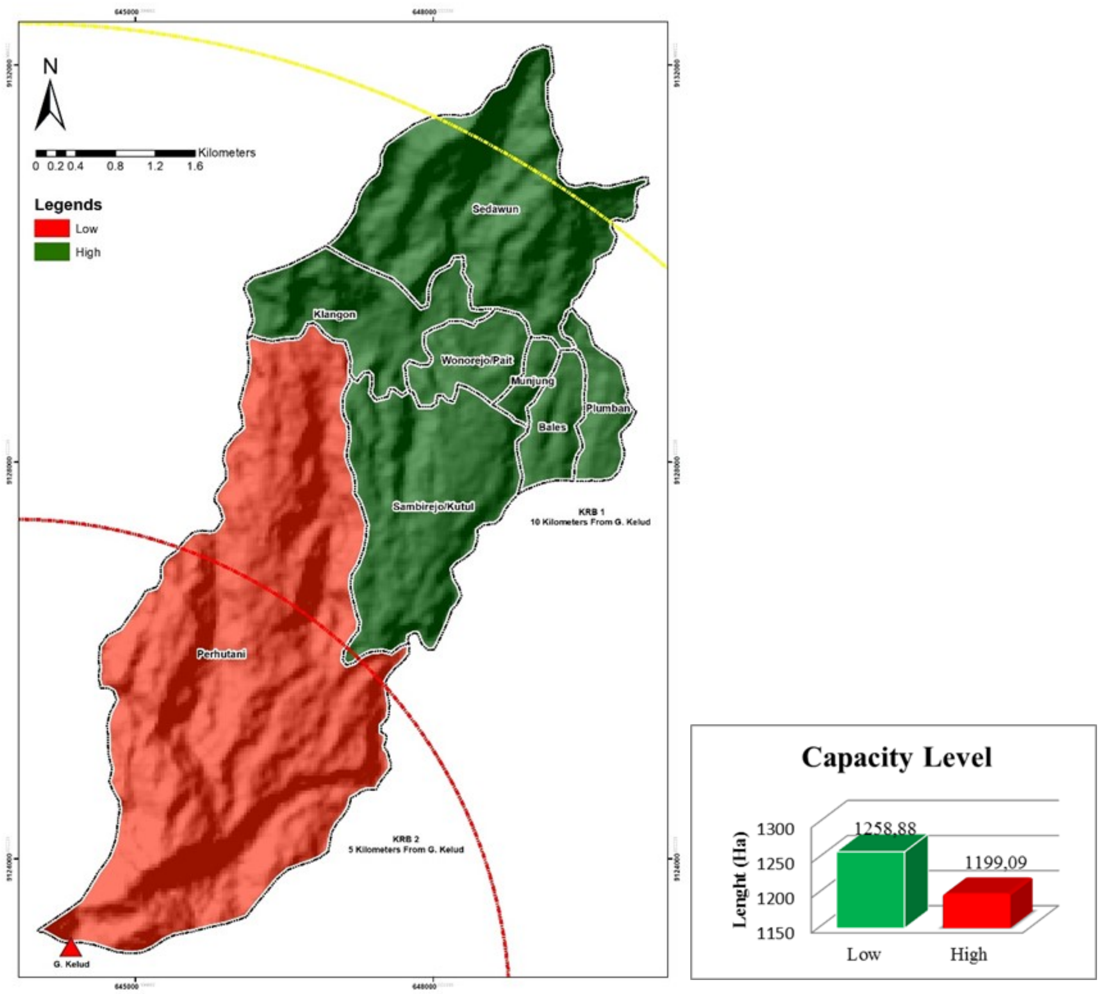

Figure 11. Maps and Diagrams of Capacity Level in Pandansari Village, Ngantang District

Figure 12. Types of evacuation facilities and health facilities in Pandansari Village, Ngantang District: a. Evacuation guides, b. Jembatan penyebrangan, c. Evacuation location (field), d.Handly Talkie, e. Evacuation location (government office), f. Health center, g. *Kentongan*

Table 9. Landslide Hazard Risk Level In Pandansari Village, Ngantang District

Land Ownership	The landslide hazard risk level (ha)			Total Luas (ha)
	Low	Moderate	High	
Dusun Plumbang	39,82	23,58	0,00	63,40
Dusun Bales	26,29	36,13	0,00	62,42
Dusun Munjung	12,04	14,17	0,00	26,21
Dusun Sambirejo	180,63	158,52	0,00	339,15
Dusun Wonorejo	31,26	50,21	0,00	81,48
Dusun Klangon	99,23	80,96	0,00	180,19
Dusun Sedawun	168,42	276,81	0,00	445,23
Perhutani	0,00	125,01	1118,77	1243,78

planning (Sudibyakto, 124: 2011). Determination of landslides risk category in this study was influenced by the variables of hazard, vulnerability, and capacity. Those variables were processed using Geographic Information System (GIS) technology so that the results of the landslides risk level in Pandansari Village could be estimated spatially.

The landslide hazard risk level in Pandansari Village, Ngantang District, was divided into 3 classes, namely low, moderate, and high. Each hamlet and land ownership in Pandansari Village has different width of landslide risk level.

The factor most influencing disaster risk level was the landslides risk factor. That was suspected due to the high category landslide hazard was the most dominating factor compared to other landslide risks in Pandansari Village. However, community vulnerability and regional capacity also have an influence in terms of increasing and reducing the risk level of landslides.

Risk and community vulnerability factors may increase the disaster risk, while capacity factor leads to the opposite. Therefore, there is a need for improvement and management efforts related to potential disaster and potential damage that may occur due to landslides hazard. Cooperation is needed from all parties involved in the efforts to increase disaster capacity and management in the areas prone to landslides. Stakeholder involvement has been widely recognized to support good disaster risk communication strategy decisions, so as to provide an overview and input for further decision making in terms of disaster management (Nadim, 2009).

Preparation of the Landslide Disaster Risk Assessment Matrix

The preparation of the landslide risk matrix in this study was based on the calculation of landslide hazard, community vulnerability, and area capacity of the Pandansari Village. The matrix preparation started with the assessment of initial landslide risk (disaster threat), involving landslide hazards parameters and community vulnerability.The estimation was carried out by connecting the two-parameter values in the matrix and the color of the meeting point symbolized the initial landslide risk (disaster threat) before the capacity or area capacity.

After the results of the initial landslide risk (disaster threat) were obtained, the values were then combined with the capacity factor to determine the risk level of the final landslide disaster.

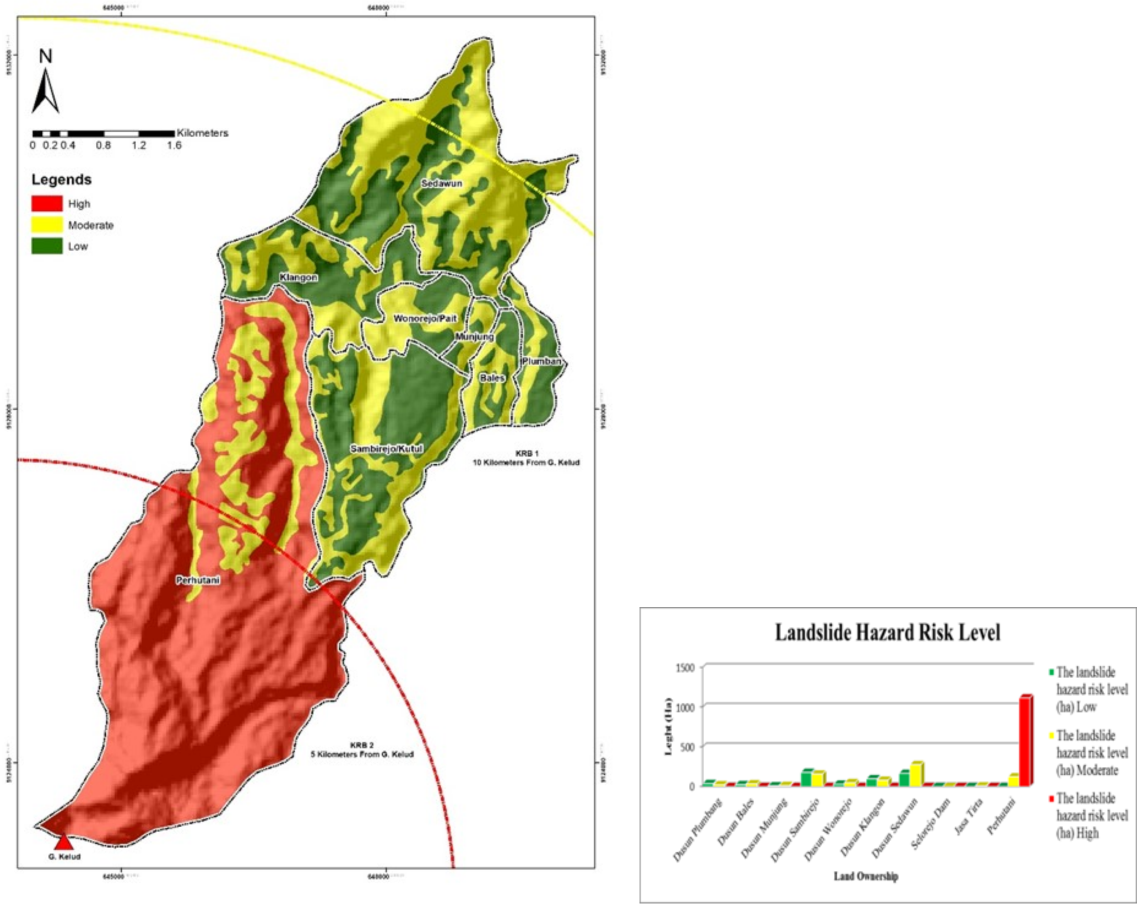

Figure 13. Landslide hazard risk level in Pandansari Village, Ngantang District

Table 10. Landslide Disaster Risk Assessment Matrix (disaster threat)

Landslide Risk (Disaster Threat)		Community Vulnerability		
		Low	Moderate	High
Landslide Hazards Parameters	Low	Low	Low	Moderate
	Moderate	Low	Moderate	High
	High	Moderate	High	High

Low
Moderate
High

Table 11. Final Landslide Disaster Risk Assessment Matrix

Final Landslide Disaster Risk Assessment Matrix		Area Capacity		
		High	Moderate	Low
Landslide Risk (disaster threat) Parameters	Low	Low	Low	Moderate
	Moderate	Low	Moderate	High
	High	Moderate	High	High

Low
Moderate
High

The preparation and results of the matrix were in accordance with the disaster risk assessment stipulated in the Regulation of the Head of BNPB Number 02 the year 2012 concerning General Guidelines for Disaster Risk Assessment. The values of each of the factors, either high or low, were used in determining and assessing the landslides risk and may influence the outcome of the landslide risk assessment. There was an interdependency between one factor and the others and all factors may influence each other so that if one factor was missing or was not included, the disaster risk assessment of the landslide hazard could not be carried out. A disaster risk assessment could be used as the basis to reduce the landslide risk, strategic plans, dissemination of disaster mitigation, policy-making in land use direction, disaster management, as well as landslide risk management and prevention to reduce the possibility of losses.

Conclusion

Pandansari Village, Ngantang District, has different landslide risks in each of the land ownership. The landslide risks were divided into three levels/categories, namely high risk with a total area of 1118.77 ha, moderate risk with a total area of 774.49, and low risk with a total area of 557.71 ha. Perhutani's land was the land with the broadest area with a high level of landslide hazards. The hamlet with the most extensive area with a moderate level of landslide hazards was Sedawun Hamlet, while the hamlet with the most extensive area of low-level landslide disaster risk was Sambirejo. The high-risk level landslide was affected by high-level landslide hazard factors, low vulnerability, and low capacity factors so that the risk level of landslides was high. The moderate level of landslide risk was influenced by high-level landslide hazard factors, moderate level of vulnerability, and high capacity factors. Finally, the low level of landslide risk was influenced by a low and moderate level of landslide disaster, a moderate vulnerability but a high level of regional capacity so that the risk level was low. Volcanic areas tend to have a higher level of risk when compared to the region located in inactive mountains. This is due to the physical condition of an active volcano that always has a source of eruption material as avalanche material as well as the socio-economic situation. According to the above result, we can conclude that landslide disasters influence not only by physical factors but also by the social aspect. Concerning landslide disaster management, this risk analysis gives comprehensive input reaching good management practice in Pandansari village.

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