THESIS

HUMAN VULNERABILITY AND COPING CAPACITY RELATED TO CARBON DIOXIDE (CO_2) VOLCANIC GASES: A COMMUNITY-BASED CASE STUDY IN DIENG PLATEAU CENTRAL JAVA

Thesis
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DISCLAIMER

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ABSTRACT

Dieng is one of the most hazardous areas in Central Java because of the craters and the eruption of volcanic gases. For several centuries, volcanic activity in Dieng has been dominated by phreatic eruptions. The most disastrous occurrence was the Timbang CO_2 emission in 1979 which caused the death of 149 people by its CO_2 volcanic gases emanation. Until now, Timbang crater always emanates CO_2 volcanic gases. Even though Dieng area is hazardous, the people in Dieng are still living in the hazardous areas. Therefore, this research has been done to discuss the origins of CO_2 volcanic gases hazard in Dieng as well as the way Dieng people deal with the hazards.

By using a case study and participatory approach, this research identified the human vulnerability of people living in Batur, Sumberrejo, and Pekasiran village in Dieng as well as disaster experience, risk perception and coping capacity towards volcanic gases. The research used both quantitative and qualitative approach to analyze the results. In order to study human vulnerability and coping capacity within the study area, questionnaires (n=70) and in-depth interviews (n=15) were carried out with the local people of the study area. A purposive sampling was drawn up based on hamlet cluster and *snowballing* techniques were applied to recruit informants. The questionnaires were analyzed by using frequency analysis, chi-square test and ordinal regression analysis using SPSS software. The results of in depth interview were analyzed and described qualitatively.

The research result shows that Simbar, Serang, and Kaliputih hamlets in Sumberejo village were the most hazardous area comparing to other hamlets in the study area. The human vulnerability discussion in this research shows that human vulnerability varies based on socio-economic characteristics and the distance between respondent's location and Timbang crater. The disaster experience and risk perception influence the thinking process and the decision making process of Dieng people especially in disaster risk reduction. For example, the evacuation patterns from 1979 to 2013 disaster shows that the disaster experiences changed as well as people have changed their risk perception based on their experience and knowledge. In addition, the coping strategies that they have are basically based on disaster experiences which transferred from generation to generation within communities. Last, the relationship between human vulnerability and risk perception were analyzed using ordinal regression analysis. The results show that the *distance, health impacts,* and *livelihood impacts* can be used as a predictor which influence risk perceptions.

Keywords: *carbon dioxide (CO_2), coping capacity, Dieng Plateau, human vulnerability, volcanic gases*

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1. INTRODUCTION

This chapter explains the general overview of the research which consists of research background, research problem, research objectives, research questions, research conceptual framework, and the limitation of the research.

1.1 Background

Volcanic gases are one of the lesser-known hazards of active volcanoes. Volcanic gases normally escape through geysers, fumaroles, and fractures in the rock. Even though volcanic gases are kind of less-known hazards, it can be the most devastating volcanic hazards and occur in large-scale. For example, large-scale eruptions of volcanic gases occurred at Lake Nyos, Cameroon in 1986. There were approximately 1,500 people and 6,000 of cattle were killed at Lake Nyos in 1986 (Le Guern, Shanklin, & Tebor, 1992). Volcanic morphologies similar to Lake Nyos are found in many other active volcanic areas, including heavily populated parts of Japan, Zaire, and Indonesia (Kusky, 2008).

Indonesia is one of the countries which is very vulnerable to natural hazards. It is located near 3 earth's plate boundaries, making it extremely prone to natural hazards especially volcanic eruptions. In Indonesia, there are 128 centers of volcanic activity, of which 78 have erupted in historical times (i.e. since c. A.D. 1600), 29 are in the solfatara stage and about 21 are solfatara fields which are not obviously connected with a volcano (Van Bemmelen, 1954). The volcanoes which are in the solfatara stage, like the Dieng Plateau, can potentially develop volcanic gases hazards.

Dieng is one of the most hazardous areas in Central Java because of the craters and the eruption of volcanic gases. For several centuries, volcanic activity in Dieng has been dominated by phreatic eruptions and geothermal activity like fumaroles, solfataras, mud pools, and hot spring (Bergen, Bernard, Sumarti, Sriwana, & Sitorus, 2000).

Allard, Dajlevic, & Delarue (1989) suggested that explosions in the Dieng complex can be distinguished into two types:

1. Eruptions without seismic precursors, resulting from self-sealing processes in active fumaroles/solfataras
2. Eruptions preceded by local or regional earthquakes or by fracture opening (e.g., Sinila-1979; Timbang explosions in the 1940s

Table 1.1 Eruptions at Dieng over the last centuries

Year	Eruption site	Phenomena	Precursors	Fatalities
1928	Timbang	flank vent, phreatic eruption, mud flow	felt seismicity, fissure opening	40
1939	Timbang	flank vent, regional fissures, phreatic eruption, mud flow	felt seismicity, fissure opening	10
1944	Sileri	central vent, explosive eruption, phreatic eruption	fissure opening	117
1964	Sileri	explosive eruption, phreatic eruption	-	114
1979	Timbang	flank vent, phreatic eruption, mud flow	felt seismicity, fissure opening	149
2009	Sileri	phreatic eruption, mud flow	-	-
2011	Timbang	flank vent	-	-
2013	Timbang	flank vent	-	-

(Source: Allard, et al. 1989; BNPB 2013; Smithsonian Institution 2014

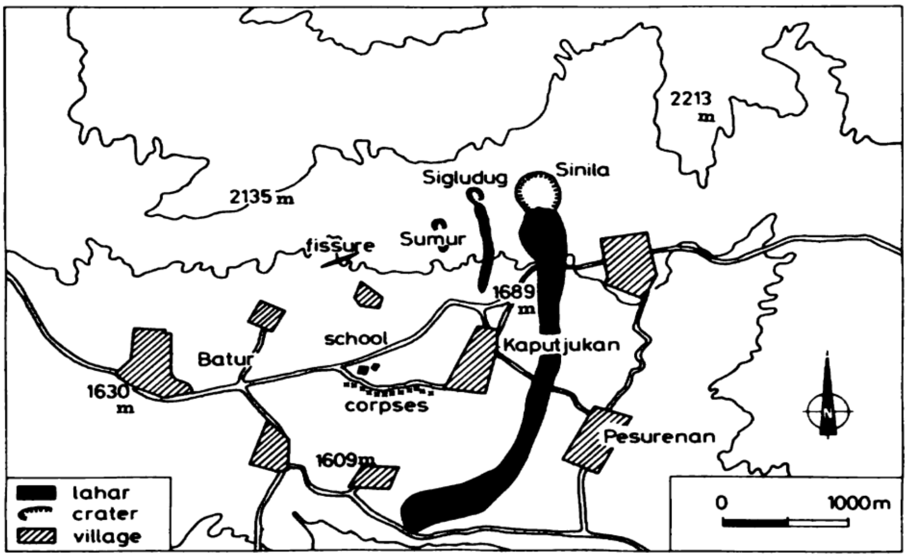


Figure 1.1 Sketch of Sinila eruption in 1979
(Source: Le Guern et al., 1982)

The most disastrous occurrence was the 1979 eruption; lethal gas cloud was released near Sigludug, known as Timbang crater. Le Guern et al., (1982) identified the lethal gas in that event as carbon dioxide (CO_2). That sudden release of lethal CO_2 (0.1 km^3) in Timbang was triggered by mild phreatic eruptions at Sinila and Sigludug craters and caused the death of 142 inhabitants (Allard et al., 1989).

It was the worst CO_2 disaster comparing to CO_2 disasters which associated with lake overturn as at Lake Monoun (1984) and Lake Nyos (1986) in Cameroon (W.F. Giggenbach, Sano, & Schmincke, 1991). It can be said that CO_2 is the most hazardous volcanic gases, even though it is a non-toxic gas in normal condition. Carbon dioxide (CO2) is a toxic gas at high concentration; it can be lethal when it reach > 15 % concentration in atmosphere (Le Guern et al., 1982).

1.2 Research Problem

Until now, the Dieng volcanic complex is still active. The craters which still actively produce CO_2 and other gases are Timbang, Sigludug and Sinila. Those craters are located in the western part of Dieng plateau which persistently emit almost pure CO_2 (moffetes) especially Timbang (Allard et al., 1989). In May 2011, March 2013, and May 2014, the status level of Timbang was changed into level III (alert) due to the increase of CO_2 gases (Liputan 6, 2013, 2014; Tempo, 2011). In addition, the CO_2 gases emitted not only in Timbang crater, but also in fissures. The type of volcanic gases in Dieng are mostly non-permanent gases, unlike in Azores and Italy (e.g. Baxter, 1999; Klose, 2007).

Carbon dioxide (CO_2) can cause asphyxia, a condition when there is a lack of oxygen or excess of CO_2 in the body. CO_2 affect not only human and animals, but also plants like in the 1979 disaster (Le Guern et al., 1982). In 2013, almost 20 ha of potato fields were damaged because of the CO_2 emission in Timbang crater (Kompas, 2013). In addition, the Dieng dwellers are still living in the hazardous areas. Even though CO_2 is very dangerous, they do not have willingness to move to a safer place because of their livelihood are located within hazardous areas. The dwellers which are mostly farmers believed that they had better knowledge of their surroundings as they were born and had lived there for years (The Jakarta Post, 2013). Based on those facts, it is interesting to know how Dieng people deal with the hazards and how they manage their livelihood towards CO_2 volcanic gases.

Vulnerability due to CO_2 volcanic gases has to be assessed. Wisner, Blaikie, Cannon, & Davis (2004) defined vulnerability as *the characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard (an extreme natural event or process).* Dibben & Chester (1999) stated that an important aspects of vulnerability is the extent to which an individual, group or community can cope with physical conditions. Since volcanic gases directly affect human health and human activities, it is necessary to analyze vulnerability and the people's ability to cope (coping capacity). The vulnerability and coping capacity is very relevant to be studied since the volcanic gases have been still gradually occurred in Dieng.

Many researchers have conducted studies related to volcanic gases disasters and vulnerabilities. The pioneer research was about CO_2 health hazard in Dieng which was conducted by Le Guern et al. (1982) . They studied that the gases analyzed in the field (Dieng) contain 98 to 99% of $CO_{2.}$ They also suggested that further research about health risk should be considered in response to protect public health towards volcanic gases. Another studies were conducted by Baxter (1999) and Dibben & Chester (1999) with the case of Furnas volcano, Sao Miguel, Azores. They both conducted researches about health hazards and human vulnerability in volcanic environments. Lavigne et al., (2008) studied about risk perception and people's behaviour of Javanese communities towards volcanic hazards on four volcanoes in Central Java including Dieng volcanic complex. Henry Ngenyam Bang (2008) studied about social vulnerability and risk perception to natural hazards in Cameroon two decades after Lake Nyos gas disaster. Kelman & Mather (2008) studied about sustainable livelihoods approach for volcano-related oportunities. They provide suggestions about living with risk by using the sustainable livelihoods approach at local level. Last, Santosa, Andreastuti, & Nursalim (2013) studied about risk assessment of volcanic hazards and the mitigation in Dieng.

Previous studies which are mentioned above show that vulnerability and coping capacity in Dieng has not been discussed yet. The Indonesian government has already conducted some surveys and research about Dieng (e.g. Santosa et al., 2013; Sudibyakto, 2011) but the research in local level has not been done yet. Indonesia still lacks of information about vulnerability and coping capacity towards volcanic gases. Therefore, this research has been done in order to fill that gap.

By using a case study and participatory approach, this research identified the vulnerability of people living near Timbang, Sigludug, and Sinila craters based on risk perception and identify coping capacity towards volcanic gases. A qualitative method was conducted to answer the research problem. Knowledge about vulnerability and coping capacity is very important in reducing the impact of the next volcanic gases occurrence.

1.3 Research Objectives

The main objective of this research is to determine the human vulnerability based on CO2 effects to human health and livelihood, also coping capacity related to volcanic gases in rural areas, a case study in Dieng Plateau, Central Java. The specific objectives are:

1. To identify CO_2 volcanic gases susceptible areas based on people's knowledge and CO_2 health effects.
2. To assess the human vulnerability
3. To identify risk perception in relation to CO_2 volcanic gases
4. To identify coping capacity and disaster management conducted by community
5. To identify the relation between human vulnerability, risk perception, and coping capacity

1.4 Research Questions

Several research questions in the following table are addressed to answer the specific objectives

Table 1.2 Research objectives and research questions

	Sub-objectives	Research Questions
1.	To identify CO_2 volcanic gases susceptible areas based on people's knowledge and CO_2 health effects	*a.* How is the spatial distribution of CO_2 toxic gases in Dieng? *b.* Which hazard mapping method is suitable for mapping the susceptibility? *c.* Where is the most susceptible area?
2.	To assess the human vulnerability	*a.* What are the characteristics of the people in the study area? *b.* What are the health and livelihood impacts of CO_2 hazard in the study area? *c.* How is the relation between location and human vulnerability?
3.	To identify risk perception in relation to CO_2 volcanic gases	a. What are community's perceptions about the CO_2 volcanic gas risk? b. What are community's perceptions about their livelihood and activities in relation to CO_2 volcanic gases?
4.	To identify coping capacity and disaster management conducted by community and local government	a. How does the community cope with CO_2 volcanic gases? b. What are the institutions involved and the role of each institution in Dieng disaster management? c. How is the availability of disaster equipment and services?
5.	To identify the relation between human vulnerability, people's perception and coping capacity	a. How is the relation among human vulnerability, people's perception, and coping capacity?

1.5 Science Significance

This research project has contributed to improve understanding about human vulnerability and coping capacity related to non-permanent CO_2 volcanic gases hazard. The type of hazard in Dieng is unique; it is a non-permanent toxic gas, unlike in Azores and Vulcano island in Italy which have permanent volcanic gas hazard. Thus the result might be different with previous research in those volcanic gas-prone areas. Nowadays, research about vulnerability and coping capacity in disaster studies are mostly related to common hazard like volcanic eruption and flood. Disaster studies still lack of research about vulnerability and coping capacity due to non-permanent volcanic gases hazard. This research should give more knowledge and fill that gap.

1.6 Research Conceptual Framework

The research conceptual framework is illustrated in Figure 1.1. The research conceptual framework shows main idea of this research which consists of the relation between physical and social environment in Dieng. The physical and social environment which then will be discussed in some themes based preliminary survey and literatures. The details of related literature study and basic theory which were used in this research will be presented in Chapter 2.

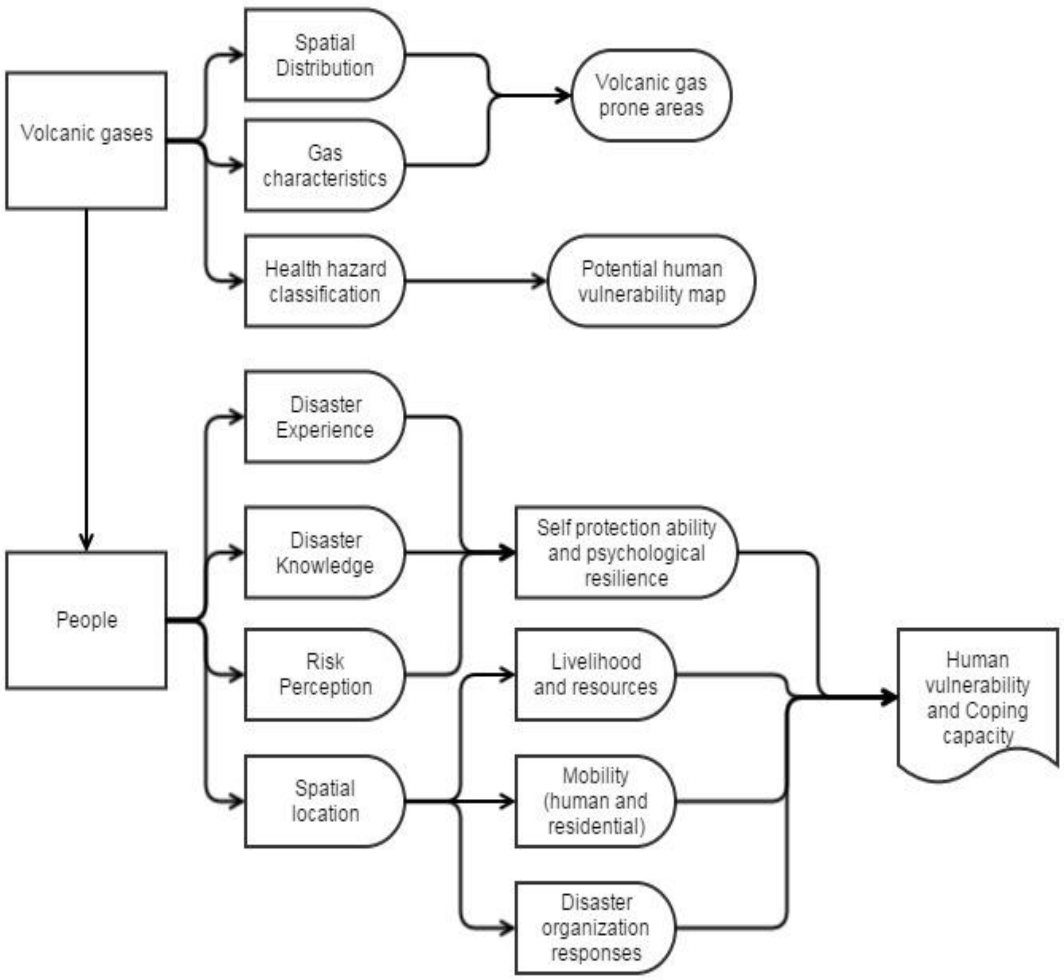


Figure 1.2 Conceptual Framework

1.6 Limitation of the Research

There are several limitations in this research. The data about volcanic gases hazard is limited only from Sinila 1979 disaster until Timbang 2013 disaster. The information related to CO_2 gas concentrations, spatial distribution of gases were obtained from secondary data of VSI publication and researches. The analysis of hazard susceptibility map is limited only based on people's knowledge about the hazardous locations, gas concentrations measured by VSI and health hazard classification based on literature study.

The human vulnerability parameters were obtained from some previous studies and also preliminary fieldwork. The health impacts were only discussed in general and were not medically assessed. The livelihood in this research means *a way of earning money in order to live* (Merriam-Webster, 2015). In terms of livelihood, this research discussed about the distance between work location and crater, the livelihood impacts in relation with the volcanic gases hazard and the way community manages their livelihood due to the gas hazard.

The outcome of the risk perception and the coping capacity may not be able to be displayed spatially. The outcome will be described narratively.

2. LITERATURE REVIEW

This chapter discusses about the related literatures to determine the basic theory and methodology which used in this research. It consists of the literature about volcanic gases, volcanic CO_2 gases and its hazard mapping, the impact of CO_2 gases, the concept of human vulnerability, risk perception, and coping capacity, community PGIS, and statistical analysis which used in this research.

2.1 Volcanic gases

Volcanic gases are part of volcanic activity. Volcanic gases contain different chemical elements. The major elements are hydrogen (H), carbon (C), oxygen (O), sulfur (S), nitrogen (N), and halogens including chlorine (Cl), fluorine (F), and bromine (Br) while the minor elements include the rare gases such as helium (He), neon (Ne), argon (Ar), krypton (Kr), and xenon (Xe) (Humaida, Sulistiyo, & Suryono, 2002). The chemical elements emerge in the form of chemical compounds, such as hydrogen in the water (as H_2), methane (CH_4), ammonia (NH_3), carbon dioxide (CO_2), sulfur dioxide (SO_2), hydrogen sulfide (H_2S), etc. The concentrations of the volcanic gas compounds vary significantly over time.

According to Veinstein & Cook (2005), the volcanic gas discharges are varied, and may be classified as follows:

1. Gases and vapors: the gaseous state of an element which normally exists in a liquid or solid form and can be readily reverted to this form by decreases in temperature or increases in pressure.
2. Aerosols: droplets or particles suspended in a gaseous medium
3. Fumes: aerosols of solid particles
4. Smoke: volatile gases and particles

The surface manifestations of volcanic gases are usually triggered by the volcano-tectonics and hydrology of the volcanic system, which being released mainly through faults/fractures (Pedro, Nemesio, Julio, & He, 2001). Based on IAVCEI research, Giggenbach et al. (2001) stated that carbon dioxide (CO_2) and the sulfur gases (H_2S and SO_2) are the predominant constituents of a volcanic gas discharges.

2.1.1 Volcanic CO_2 gases

One of the most notorious volcanic gases is CO_2. It is heavier than air and may pool at ground level. At high concentration, it can be lethal when it reaches > 15 % concentration in atmosphere (Le Guern et al., 1982). Volcanic CO_2 gases normally escape through geysers, fumaroles, and fractures in the rock. Volcanic CO_2 gases can also be released without obvious volcanic activity (*degassing*). It can escape diffusely through the soil (e.g. Furnas, Auckland), overlying lakes (e.g. Lake Nyos and Lake Monoun in Cameroon) and also groundwater (Le Guern et al., 1992; Smid & Mazot, 2012; Viveiros et al., 2010). In active volcanoes, CO_2 is often diffusively emitted during and between eruptive cycles (Smid & Mazot, 2012). In summary, volcanic CO_2 sources can be divided into several categories: direct and diffuse degassing from active volcanoes, diffuse degassing from inactive volcanoes and regional diffuse degassing from intrusive tectonic structures (Burton, Sawyer, & Granieri, 2013).

Volcanic CO_2 emissions can be hazardous and cause catastrophes. The CO_2 are most dangerous where they can build up in low-lying areas such as natural topographic depressions, excavations and pits, and then flow along downslopes. There are some places which experienced CO_2 disasters, such as Vulcano (Italy), Lake Nyos and Lake Monoun (Cameroon), Nyiragongo (Congo) and Dieng Plateau (Indonesia). The most devastating disaster was Lake Nyos disaster, large-scale eruptions of volcanic gases occurred at Lake Nyos, Cameroon in 1986. There were approximately 1,500 people and 6,000 cattle were killed at Lake Nyos in 1986 (Le Guern et al., 1992). For more details, Table 2.1 below shows volcanic CO_2 emissions incidents over the last century:

Table 2.1 Volcanic CO_2 emissions incidents over the last century

Volcano	**Date**	**Mortality/Morbidity**	**Reference**
Vesuvius	18 April 1906	1 death	(Perret, 1924)
Dieng, Indonesia	1928	40 deaths	(Newhall & Dzurisin, 1988)
Dieng, Indonesia	1939	10 deaths	(Newhall & Dzurisin, 1988)
Nyamuragira (Kituro)	1948 (?)	1 injury	(Le Guern et al., 1982)
Heimaey, Vestmannaeyjar, Iceland	23 January 1973	1 death	(Thorarinsson, 1979)
Dieng, Indonesia	20 February 1979	~149 deaths 1,000 injuries	(Cronin & Sharp, 2002; Le Guern et al., 1982)
Lake Monoun, Cameroon	16 August 1984	37 deaths 1 injury	(Sigurdsson et al., 1987)
Lake Nyos, Cameroon	21 August 1986	1,746 deaths >845 injuries	(Othman-Chande, 1987)
Vulcano, Italy	1980's	2 deaths	(Baubron, Allard, & Toutain, 1990)
Mammoth Mountain, USA	March 1990	1 injury	(Sorey et al., 1998)
Rabaul, Papua New Guinea	24 June 1990	6 deaths	(Itikarai & Stewart, 1993; Veinstein & Cook, 2005)
Hakkoda, Japan	12 July 1997	3 deaths	(Hayakawa, 1999)
Mammoth Mountain, USA	24 May 1998	1 death	(Hill, 2000)
Alban Hills Volcanic District, Italy	December 2000	1 death	(Beaubien, Ciotoli, & Lombardi, 2003; Carapezza, Badalamenti, Cavarra, & Scalzo, 2003)
Nyiragongo, Congo	January 2002	2 injuries	(Baxter & Ancia, 2002)

2.1.2 Volcanic CO_2 gases hazard mapping

As volcanic CO_2 gases are hazardous, it is important to conduct hazard mapping in order to know the hazardous area within particular places. The hazard map is usually made based on previous disaster occurrence, or it can be also made based on measurements using particular methodologies. Thus, the hazard map can be understood as the spatial extent of disasters (which already happened) and also as the spatial extent of susceptible area (potential susceptibility).

There is no precise methodology or scientific standards which explain methods to make volcanic CO_2 gases hazard mapping. Since the gas influenced by not only endogen factors, but also influenced by meteorological factors such as wind and pressure, it is very difficult to conduct or modelling this type of hazard. The CO_2 hazard mapping also depends on the source of the gas. For example, soil gas mapping will be different with fumaroles/moffetes gas mapping, or with hazard event mapping. The parameters will be different among hazard maps. Table 2.2 below shows the list of hazard mapping which have been made in previous studies:

Table 2.2 Volcanic CO_2 gases hazard mapping in previous studies

Volcano	**Hazard map type**	**Mapping methods**	**References**
Dieng, Indonesia	Event map (polygon)	Sketch	(Le Guern et al., 1982)
Lake Nyos, Cameroon	Event map (polygon)	Sketch based on missionary reports	(Baxter, Kapila, & Mfonfu, 1986)
Furnas, Portugal	Soil gas map (polygon)	Measurement in soils at 70 cm depth. The classification is based on risk of asphyxia	(Dibben & Chester, 1999)
Cerro Negro,	Soil gas and efflux	Measurements	(Pedro et al.,

Volcano	Hazard map type	Mapping methods	References
Nicaragua	map (dots and isolines)	were done using accumulation chamber method. Kriging was used as interpolation method to construct contour map	2001)
Dieng, Indonesia	Moffet and soil surface gas (isolines)	Measurements used Giggenbach method. Contour mapping method used interpolation.	(Humaida et al., 2002)
Furnas, Portugal	Soil gas map (dots and polygon)	Methods used Sequential Gaussian Simulation (sGs)	(Viveiros et al., 2010)

The hazard maps which have been made should be updated. The proper geospatial information about volcanic CO_2 is required in order to know the hazardous area as volcanic CO_2 gases are dangerous and threaten human life.

2.1.3 Human impact of volcanic CO_2 gases

At high concentration, carbon dioxide (CO_2) can cause asphyxia, a condition when there is a lack of oxygen or excess of CO_2 in the body. Carbon dioxide shows the effect of an inert asphyxiant gas which can replace oxygen in the body, but does not have a directly toxic effect on tissues (Veinstein & Cook, 2005). Volcanic CO_2 gases affect not only human and animals, but also plants like in the Dieng 1979 disaster in Indonesia (Le Guern et al., 1982). Le Guern et al. (1982) conducted a study about CO_2 emissions in Dieng and found that the gases analyzed in the field (Dieng) contain 98 to 99% of CO_2, which the concentration was very high and could be lethal.

Human health effects due to volcanic CO_2 gases have been examined in some previous medical volcanology researches. Previous studies showed that there is correlation between the gas concentration value and human impacts. The higher the CO_2 concentration, the impact on health will be higher. The CO_2 concentrations under 0.5 % in air are safe and tolerable. Low concentrations under 5 % can produce accelerated breathing, confusion, headache, and vertigo will be the early symptoms. If the concentrations higher (for example, concentrations of 8-10% endured in a few minutes), human can experience fainting, severe headache, confusion, and sweating. The elevated levels of CO_2 in the bloodstream (*hypercapnia*) will eventually result in circulatory failure and death from acidosis (Veinstein & Cook, 2005). Table 2.3 shows the effects of CO_2 on the respiratory centers, United States Federal Register, 1970 in (Le Guern et al., 1982):

Table 2.3 The effects of CO_2

Concentration of CO_2 in air (%)	**Effects**
0.1 -1 %	Increase lung ventilation
2 %	50 % increase lung ventilation
3 %	100 % increase lung ventilation
5 %	300 % increase lung ventilation
10 %	Can be endured for only a few minutes
12 – 15 %	Soon causes unconsciousness, death occurs by lack of oxygen

From Table 2.3, it can be seen that the elevated concentration of CO_2 can increase human breathing rate. In addition to that, Health and Safety Executive from UK Government, (HSE, 2013), studied about the change in human breathing volume in response to CO_2, it can be seen in the figure below:

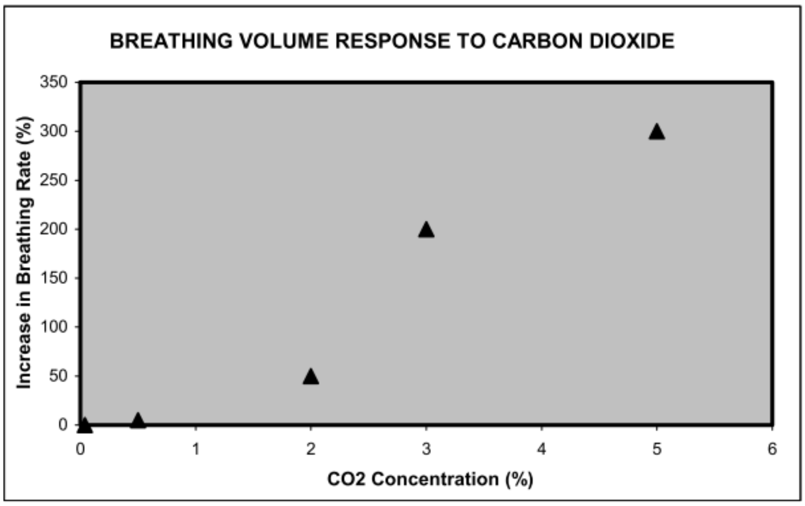


Figure 2.1 Breathing volume response to CO_2 concentrations
(Source: HSE, 2013)

There are some studies which explain the relation between CO_2 concentrations and the human responses. Table 2.4 below is the compilation of CO_2 effects from previous studies:

Table 2.4 Carbon dioxide (CO_2) concentration range and the impacts

(Source: Baxter, 1999; Le Guern et al.,1982; Rice, 2003)

Concentration of carbon dioxide (%)	**Responses**
< 0.5 %	Safe and tolerable
1 %	Respiratory rate increase 37%
1.5 – 7.99 %	Brain blood flow, dizziness, confusion, dyspnea, headache, respiratory rate increase up to ~200%
8 –10 %	Severe HA, dizziness, confusion, dyspnea, sweating, dim vision
10-24.99 %	Unbearable dyspnea, followed by vomiting, disorientation, hypertension, & loss of consciousness
> 25 %	Soon causes unconsciousness, death occurs by lack of oxygen (asphyxia)

2.1.4 Volcanic CO_2 gases and other impacts

Volcanic CO_2 gases do not only affect human life, but also affect plants and animal life. In areas with high CO_2 concentrations, plants and various animals also perished. In Dieng 1979 disaster, plants had been perished and trees had been stripped of their leaves up to 1.7 meter above the ground level (Le Guern et al., 1982). In some places, the CO_2 destroyed the surrounding vegetation (Allard et al., 1989). In plants, CO_2 actually activates photosynthesis, even at high concentrations, but in Dieng the leaves had died from lack of oxygen. In Lake Nyos 1986 disaster, the taller vegetation had been partially flattened in a few places along the lake and lower Nyos (Baxter & Kapila, 1989). Animal life has been also affected by toxic CO_2 gases. In Lake Nyos, almost 6,000 of cattle were perished. Besides livestock, CO_2 gases also killed wild birds, amphibians, reptiles, and insects indiscriminately (Fomine, 2011). In Dieng, animal life also had been killed by CO_2 gases, seen in the figure below:

Figure 2.2 Weasel killed in Timbang emissions (2013)
(Source: Surip, PGA Dieng)

Volcanic CO_2 gases also affect livelihood. In a commonplace meaning, livelihood is a way of earning money in order to live. Disaster is a "shock" condition which can cause economic implications on people lives. For example, rural people can totally lose job or (temporary) if their land were affected by CO_2 gases. In addition, people can also lose their houses, or they may be lead to starvation. If the disaster occurs, people have to cope in order to survive. In Lake Nyos disaster, a total of 1,642 hectares of land were abandoned in the affected villages and these had profound economic implications on the lives of the survivors in the entire areas (Fomine, 2011). Food crops such as maize, cassava, yams, groundnuts, and soya beans that were already growing on the land were forsaken because of CO_2 toxic gases. This led to starvation in the Lake Nyos area. In Dieng, almost 20 ha of potato fields were damaged because of the CO_2 emissions in Timbang crater (Kompas, 2013). Based on those facts, it is important to know how people deal with the hazards and how they manage their livelihood towards CO_2 volcanic gases.

2.2 Vulnerability

2.2.1 The concept of vulnerability

In a commonplace meaning, vulnerability means: being *prone to* or *susceptible to* damage. The idea of vulnerability may differ based on different perspectives. In some recent studies, vulnerability concept is often correlated with the notion of poverty or marginality. But in fact, it is difficult to read vulnerability by correlating poverty directly, particularly in terms of disaster. Theoretically, Wisner et al (2004) defined vulnerability as *the characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard* (an extreme natural event or process). UNISDR (2009) defined vulnerability as *the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of hazard*. In summary, vulnerability is the characteristics which attached in individual or household or communities that are susceptible and influence their capacity to cope with disasters.

Before discussing vulnerability framework/theory which used in this research, it is important to know what kind of 'streams' in theories which exist in vulnerability studies. According to Wisner et al., (2004), there are at least four major streams of vulnerability theory that should be acknowledged. First, some studies give more emphasis to people's 'capacity' instead of the 'vulnerability'. They tend to focus on socio-economic and political processes that make people 'vulnerable'. The second is about the increasing of interest in trying to quantify vulnerability as a tool of planning and policy making. Because of this, there have come debates about quantitative and qualitative data, which one is more reliable than other. Also, it is important to question about the possibility in quantifying the vulnerability.

Thirdly, the concept of vulnerability is mostly about the potential loss (which often expressed as an objectively assessed statistical probability) multiplied by the magnitude of hazard. The conversion of 'risk' is turned into a common metric, which make it *measurable* and *comparable* but not always precisely meaningful. Some authors which use this kind of concept tend to under-emphasize the cultural, the psychosocial and human aspects of disaster impacts.

Fourthly, there is a movement away from the notion of 'vulnerable groups' to a concern with 'vulnerable situations'. The research and works nowadays tend to be more focus on the amount of potential loss (e,g, building losses, economic losses, etc) instead of discussing about who is the vulnerable people and what exactly is the characteristics of vulnerable people. Wisner et al., (2004) stated that vulnerability refers only to people, not to buildings (susceptible, unsafe), economies (fragile), nor unstable slopes (hazardous) or regions of particular earth surfaces (hazard-prone).

According to Cardona (2001) (cited in Bankoff, Frerks, & Hilhorst, 2004), vulnerability originates in:

- Physical fragility or exposure: the susceptibility of a human settlement to be affected by a dangerous phenomenon due to its location
- Socio-economic fragility: disadvantageous conditions and relative weaknesses related to social and economic factors
- Lack of resilience: an expression of the limitations of access and mobilization of the resources of human settlement

2.2.2 Human vulnerability analysis

Human vulnerability is dynamic. It is identified through the study of past events and the simulation of future disasters. Wisner et al., (2004) proposed a dynamic framework for vulnerability called Access model framework. This framework was designed to understand the complex and varied sets of social system that may be associated with disaster. This framework is very useful for planning and policy making. However, the scope for using this framework as a research design is very wide. For a brief, Figure 2.3 below shows the Access model in outline, taken from Wisner et al., (2004):

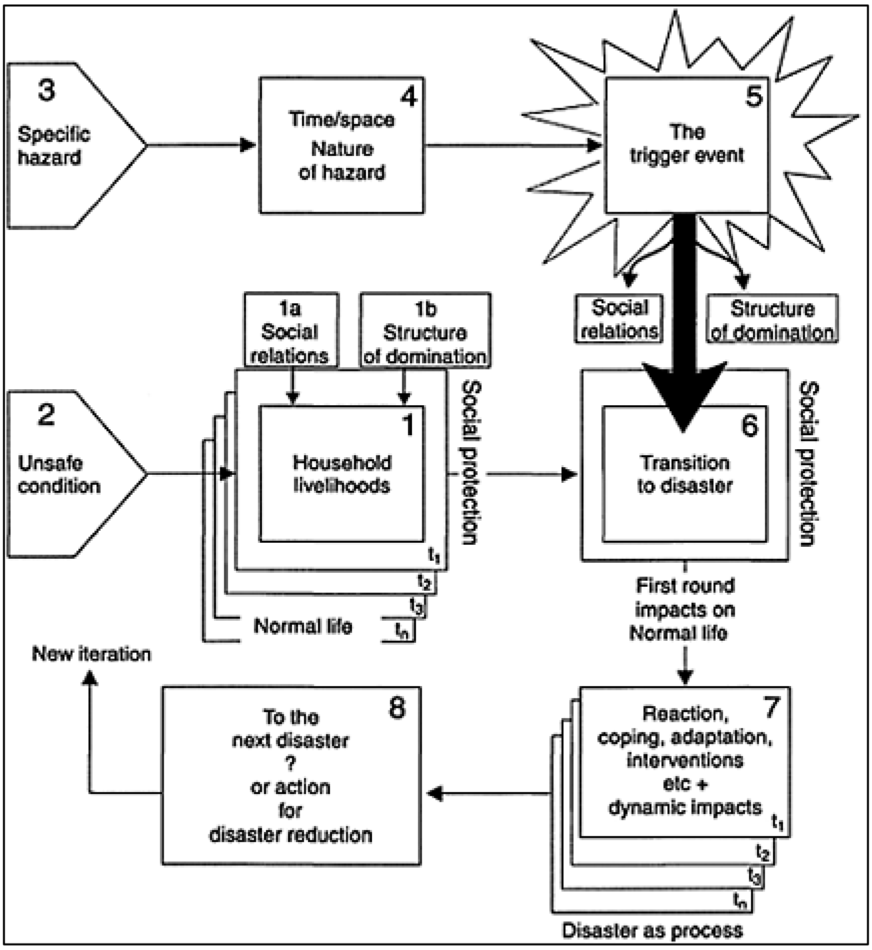


Figure 2.3 The Access model in outline
(Source: Wisner et al., 2004)

Another method for assessing vulnerability is Vulnerability and Capacity Assessment (VCA) which emphasis on participatory and community approaches. Based on Davis,.et al (2004), the aims of VCA are:

1. Identify and measure the vulnerable individuals/groups, based on characteristics such as gender, age, health status, ethnicity, etc.
2. Analyze the density patterns, livelihood security and occupational activities that increase the vulnerability of particular communities.
3. Identify the resources such as community coping strategies, local leadership and institutions, and existing social capital which may contribute to risk reduction efforts.
4. Identify local perception of risk, which has an important role in determining risk and mitigation measures.

Another framework which particularly discuss about vulnerability and volcanic hazard was proposed by Dibben & Chester (1999). Dibben & Chester (1999) proposed a vulnerability framework for volcanic hazards which covered residential mobility, attitudes to the village (social and physically), risk perceptions, disaster preparation, and attitudes to hazard mitigation measures. They defined vulnerability as the extent to which the interaction of hazards and society will lead to depression of an individual's basic needs and their satisfiers, leading to a less social participation. This is described as an individual's *susceptibility*. In this framework, the *susceptibility* depends on:

1. Location of activities and home
2. Self-protection ability
3. Physiological and psychological resilience
4. Livelihood and resources
5. Emergency organization responses
6. The reaction of family, communities, social organizations and society in general.

The aspects of susceptibility may be subtractive or additive (Dibben & Chester, 1999). For example, elder people may have poor *self-protection ability* because of their physics, but they may have a better knowledge about particular hazard (*psychological resilience*) that leads to a safer condition, or vice versa. Thus, it is quite difficult to generalize the human vulnerability into something that can be quantified. Vulnerability is always dynamic and specific. What can be done is identify all of the aspects of susceptibility and describe it empirically. This research uses (Dibben & Chester, 1999) vulnerability framework as research design which include risk perception and coping capacity.

2.3 Risk Perception

Vulnerability is about people, including their perceptions and knowledge (Bankoff et al., 2004). People's thoughts and knowledge influence their decision making in all aspects in life. People's perceptions about risk in relation to disaster create practices/responses that may increase or decrease the vulnerability. Perception is important in understanding why people do certain behaviors (Bankoff et al., 2004). In some disaster literatures, perception is usually called as *risk perception*.

Risk perception is a terminology which commonly used in disaster studies. Plapp & Werner (2006) stated that risk perception is an everyday subjective assessment process that is based on experience and on available information without referring to reliable data, series and complex models. The perception of risks involves the process of collecting, selecting, and interpreting information about uncertain impacts of events, activities or technologies (Wachinger et al., 2010). Knowledge, experience, values, attitudes, and feelings that people have influence the thinking process and the decision making about the disaster risks. The way people perceive risk will lead to coping practices in relation to disaster.

In disaster studies, risk perception has been investigated using various risk measures. The risk measures can vary from the magnitude of risk, probability of an event, estimated loss, etc. If risk perception of people living in hazard prone areas is known, effective information strategies on preventive and protective measures can be designed (Plapp, 2001). Thus, it is important to identify risk perceptions in order to analyze the human vulnerability and coping capacity.

2.4 Coping Capacity

In disaster studies, coping capacity has multi definitions. UNISDR (2009) defined coping capacity as "*the ability of people, organizations and systems, using available skills and resources, to face and manage adverse conditions, emergencies or disasters*". Just like vulnerability, coping capacity also has a time dimension. It requires a continuing awareness, resources and good management, both in normal times as well as during the crises (UNISDR, 2009). Coping capacity is known by looking the strategies and practices that people do in order to cope with disaster. Bankoff et al., (2004) stated that coping practices is the strategies adopted by communities to reduce the impact of hazard or avoid the occurrence of disaster. It is commonly based on the assumption that what has happened in the past (the disaster) is likely to happen in the future. Thus, coping capacity is usually related to disaster experience and risk perception. The more they have experiences, the more they know how to cope with the disaster.

2.5 Community and Participatory *Geographic Information System* (PGIS)

Community is a group of people who live in the same area such as city, town, or neighborhood (Merriam-Webster, 2015). In this research, the community is a group of people who live in Dieng plateau particularly within the study area (further description in Chapter 4). Communities are the ones who vulnerable to disaster. In disaster studies, the participation of community is essential in disaster risk reduction. Since the community has lived in their neighborhood for years, they might also have a lot of local knowledge and experiences over time. Thus, community participation is essential both in gathering information about the hazard and also the disaster management. The method which commonly used to conduct community-based participation is participatory GIS.

Participatory GIS is one kind of mapping methods in geo-information science. Participatory GIS has become increasingly used in social research especially community-based research. In disaster studies, the integration of local knowledge and geographical information system is important for disaster management. The integration of community perceptions of risk with geo-information is a useful step in the identification and analysis of hazard and vulnerability. It can become a valuable tool in disaster risk reduction (Krishnamurthy, Fisher, & Johnson, 2011).

2.6 The theory of statistic

Statistics is one of disciplines which concerned with scientific methods for collecting, organizing, summarizing, presenting and analyzing data, as well as drawing conclusions and making reasonable decisions on the basis of such analysis (Spiegel, 1961). There are many statistical methods which can be used in scientific research. The statistical methods are used based on the research objectives as well as the type of data.

This research uses some of statistical analysis: frequency analysis, Chi-square analysis, and ordinal logistic regression. Frequency analysis is the most common and simple analysis in statistic. Frequency analysis is a descriptive statistical method which shows the number of occurrences of each response chosen by the respondents. Meanwhile, Chi-square is the statistical method used to determine the association or relationship between two categorical variables (X^2 or the Chi-square) (Spiegel, 1961). In Chi-square analysis, the degree of freedom (*df*) and Chi-square (X^2) are analyzed to determine whether there is a significant relationship or not between two categorical variables.

The ordinal regression is one of regression methods which estimated how ordinal data (as dependent variable) can be predicted based on the value of one independent variable. The ordinal regression differs with linear regression. In linear regression, R^2 (the coefficient of determination) summarizes the proportion of variance of in the outcome of analysis. Meanwhile, for ordinal regression models it is not possible to calculate the same R^2 as in linear regression, thus in ordinal regression there is only pseudo R^2. Before analyze the ordinal regression model, it is important to examine the data and fit the model. Model fitting is a standard statistical tool for testing whether a model fits or not (between observed and expected values); model fitting uses chi-square score in the analysis. After the model fits, further analysis of ordinal regression can be done by analyzing the *parameter estimated values* and the significant coefficient ($p < 0.05$). The frequency analysis, chi-square analysis, and ordinal regression analysis in this research will be done using SPSS software.

3. STUDY AREA

This chapter describes about the study area which consists of general overview of Dieng plateau, geological setting of Dieng, Dieng eruption histories, study area focus, and land use in the study area.

3.1 Dieng Plateau

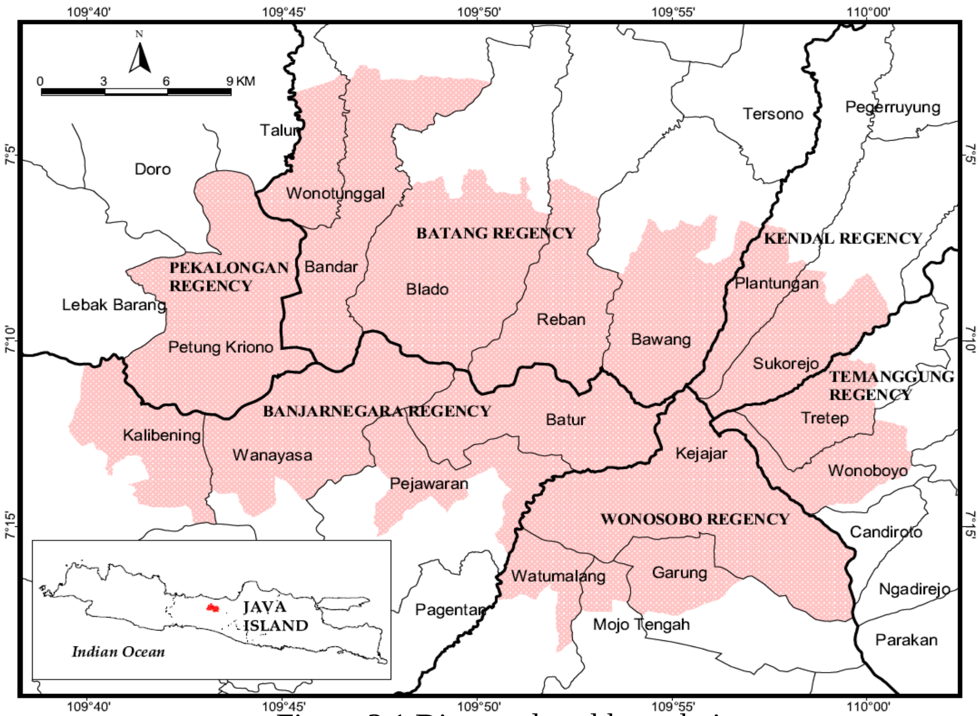


Figure 3.1 Dieng cultural boundaries
(Source: Peraturan Gubernur Jawa Tengah No. 5 Tahun 2009

Study area in this research is located in Dieng Plateau. The Dieng Plateau is a volcanic complex in Central Java, at about 1600-2000 meter above sea level. It belongs to a series of Quaternary volcanoes, which includes the historically active Sumbing and Sundoro volcanoes (Bergen et al., 2000). The Dieng Plateau is utilized as a complex of agricultural areas for vegetables and also as a tourism destination. On the contrary, Dieng is one of the most hazardous areas in Central Java because of the volcanic eruptions and toxic volcanic gas emissions.

There is no absolute boundary that explains the extent of Dieng Plateau. Dieng Plateau can be delineated both physically and culturally. Figure 3.1 shows the Dieng cultural boundaries based on spatial distribution of Dieng society from

Peraturan Gubernur Jawa Tengah No. 5 Tahun 2009. Dieng Plateau can also be shown topographically; it can be seen as a highland area which consists of crater, lake, and peaks as shown in Figure 3.2. Administratively, Dieng Plateau is mostly situated on Banjarnegara Regency and Wonosobo Regency. The study area focus on this research is not the entire Dieng Plateau. It is only some sub-areas which will be investigated. The study area focus will be explained on sub-chapter 3.4.

Figure 3.2 Dieng Plateau, Central Java
(Source: Data processing)

3.2 Geological setting of Dieng

The Dieng Plateau consists of tectonic and volcanic settings (Figure 3.3) and is still active, making it extremely prone to volcanic hazards. Dieng Plateau is an area which surrounded by the relics of two or more stratovolcanoes (Sukhyar, Sumartadipura, & Effendi, 1986). It contains two intersecting sets of faults—an E-W or ESE-WNW set that cuts straight through the plateau, and a N-S or NNE-SSW set that is expressed in the Butak Petarangan-Dringo area in the northwest part of the plateau and near Pakuwojo in the southeast part of the plateau (Delarue, 1980; Sukhyar et al., 1986). Some geologists, Junghuhn (1853/54)

Verbeek and Fennema (1893), considered that Dieng is an ancient huge caldera, but they did not know of any deposit that can be correlated with caldera formation (Newhall & Dzurisin, 1988).

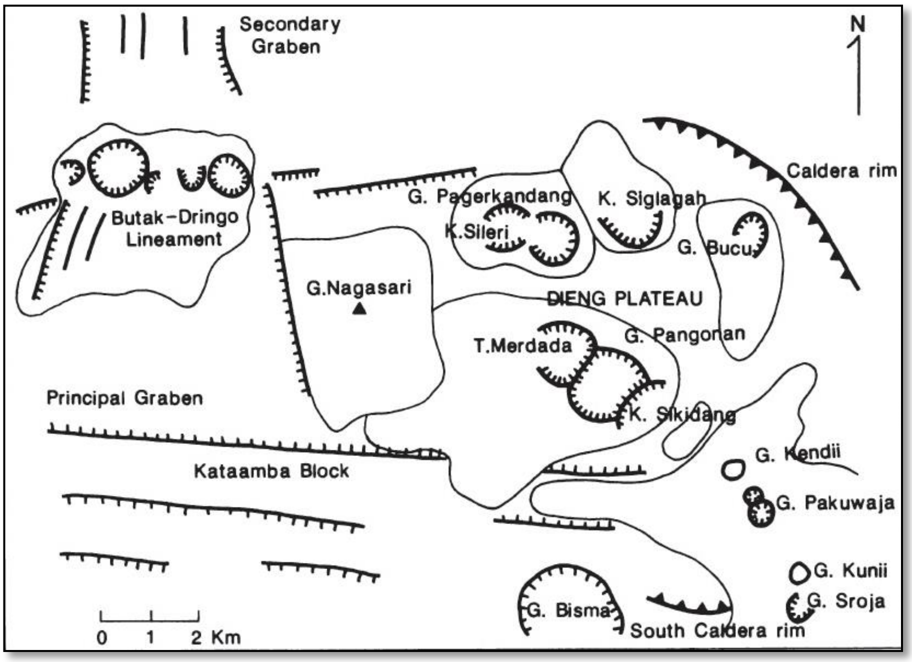


Figure 3.3 Sketch map of Dieng Plateau, modified from Delarue (1980) in Newhall & Dzurisin (1988)

According to Sukhyar (1994), the oldest volcanoes are Prahu and Tlerep stratovolcanoes and also the Rogojembangan units. The oldest volcanic products have a Lower Quarternary age and form the northern and southern margins of the Dieng Plateau. The western part of the Prau cone (+2565m) has been subsided and formed the plateau. The subsidence explains the landform which has been interpreted as a caldera or as a structural depression. The Nagasari cone is probably the western border of the plateau (see Figure 3.3).

There are numerous surface manifestations in Dieng, such as hydrothermal activity (lakes, fumaroles/solfatara, mud pools, hotsprings), geothermal resources and toxic gas sources. The eastern area of Dieng is dominated by geothermal resources and some fumaroles/solfatara, while the western area is dominated by craters which potentially emit CO_2 toxic gas and natural CO_2 toxic gas sources (moffettes). Thus, the western area of Dieng Plateau was selected to be the study area (sub-chapter 3.4).

3.3 Dieng Eruption Histories

The Dieng Plateau has almost never erupted magmatic eruption, but dominantly a phreatic eruption. According to Delarue (1980), the frequent phreatic eruptions in Dieng are about 70 in the eastern and central parts of the complex and about 30 in the western Batur sector. The Dieng activity histories are listed in the Table 3.1 below:

Table 3.1 Dieng activity over the last centuries

No	Year	Site	Phenomena	Precursors	Fatalities
1	1786	Kawah Candradimuka	Earthquake occurred for four months followed by eruption and formed various vents which emitted sulphureous vapour	-	-
2	1826	Pakuwojo	Strong explosions and earthquake	-	-
3	1847	Unknown vent	Small eruption occurred on 4 October 1847	-	-
4	1884	Kawah Banteng, Kawah Sikidang	Increasing of solfataric and fumarolic activity, including mud eruptions	eruptive activity of Sundoro	-
5	1924	Along N-S Dieng fault	A strong earthquake occurred near Wonosobo	felt seismicity, fissure openings	-
6	1928	Kawah Timbang	Strong earthquakes occurred and accompanied by opening of NNE-SSW fissures near Timbang. Eruption began shortly from three new craters along NNW fissure. ***Strong CO_2 emission continued at least until 1937.***	fissure opening, small eruptions	40

(Table continued)

No	Year	Site	Phenomena	Precursors	Fatalities
7	1939	Kawah Timbang	Seismic swarm occurred in October 1939 followed by small phreatic eruptions from at least 15 craters. ***CO_2 emission was moderate, less than in 1928-1937.***	Seismic swarm, fissure opening	10
8	1943	Kawah Sileri	Many small N-S fissures appeared north-west of the Sileri.	-	-
9	1944	Kawah Sileri	On 3 November 1944, two phreatic explosions formed small craters. On 4 December 1944, a strong phreatic explosion killed 114 persons	No earthquake were felt before or during this eruption	114
10	1952	Kawah Timbang	***Increased CO_2 emission*** began near Timbang in August 1952 accompanied by several small felt earthquakes	-	-
11	1953	Kawah Timbang	***Increased gas emission*** and light ashfall occurred near Keputjukan (southern Timbang) on 21 March 1953	-	-
12	1956	Kawah Sikidang and Kawah Sileri	***Increased steaming and gas (CO_2?)*** emission from Sikidang crater in March 1956 and from Sileri crater in June 1956	-	-
13	1964	Bitingan and Kawah Sileri	A fumarole field at Bitingan enlarged during December 1964. A small phreatic eruption occurred from Sileri crater on 13 December 1964.	-	-
14	1965	Kawah Timbang	Seven weak earthquakes were centered near Timbang and felt in nearby Batur in May 1965. ***There was an apparent increase in emission of CO_2 and H_2S, which***	Weak earthquakes	-

(Table continued)

No	Year	Site	Phenomena	Precursors	Fatalities
			produced a ground-hugging gas layer reaching 1 m above ground level in August 1965.		
15	1979	Kawah Sinila, Kawah Timbang	Six weak earthquakes were recorded on 16 February and one on 19 February 1979. On 20 February, earthquakes were felt over a radius of 10 km. An eruption began at 5 am from Telago Sinila (Sinila Lake) in the area of N-S faulting along the side of Butak Petarangan complex. At 6.15 am another small eruption occurred from Sigludug zone (250 m west of Sinila). ***CO_2 was emitted from N-S fissure, together with H_2S and CH_4. CO_2 displaced oxygen in the air (become lethal) and killed 149 people.***	Weak earthquake, fissure opening	149
16	1981	Kawah Sinila	Small earthquake swarm occurred	-	-
17	1984	Kawah Sileri	Earthquake swarm began on 10 October 1984	-	Damaged a few buildings
18	1986	Dieng	A widely felt earthquake occurred near Dieng on 13 April 1986	-	-
19	1990	Kawah Dieng Kulon (near Timbang)	Phreatic eruption	-	-
20	2011	Kawah Timbang	Earthquakes and ***emission of CO_2*** and H_2S from Timbang crater, which produced a ground-hugging gas layer reaching 1 m above ground level	-	-

(Table continued)

No	Year	Site	Phenomena	Precursors	Fatalities
21	2013	Kawah Timbang	Earthquakes and ***emission of CO_2*** and H_2S, which produced a ground-hugging gas layer reaching 1 m above ground level	-	Damaged a few buildings in Pekasiran

(Source: Allard, Dajlevic, & Delarue, 1989; Newhall & Dzurisin, 1988, BNPB 2013, Smithsonian Institution 2014)

Dieng activity is not only phreatic eruption but also rifting or fissure opening (see Table 3.1 above). The activity at Dieng illustrates relations between rifting and phreatic eruption. It illustrates the volcanic hazard by accumulations of volcanic gases in Dieng especially near crater, along the faults, and in low-lying areas.

3.4 Study area focus

The study area is located in Batur Sub-district, western area of Dieng Plateau. Batur Sub-district was selected because it is prone to Kawah Timbang eruptions, especially the CO_2 gases effusion. Batur Village, Sumberejo Village, and Pekasiran Village were selected as the study area focus (see Figure 3.4). The study area focus consists of 21 hamlets included in those 3 villages. The hamlets are:

1. Batur Village: Bandingan, Maja Tengah, Kalianget, Purwojiwo, Bujangsari, Karanganyar, Batur Kidul, Batur Tengah, Batur Lor, Tlagabang, Jlegong, Bakalan, and Tieng
2. Sumberejo Village: Simbar, Serang, Sumberejo Satu, Sumberejo Dua, and Kaliputih
3. Pekasiran Village: Argomukti, Santren, and Sidomulyo

The map of study area is shown in the Figure 3.4:

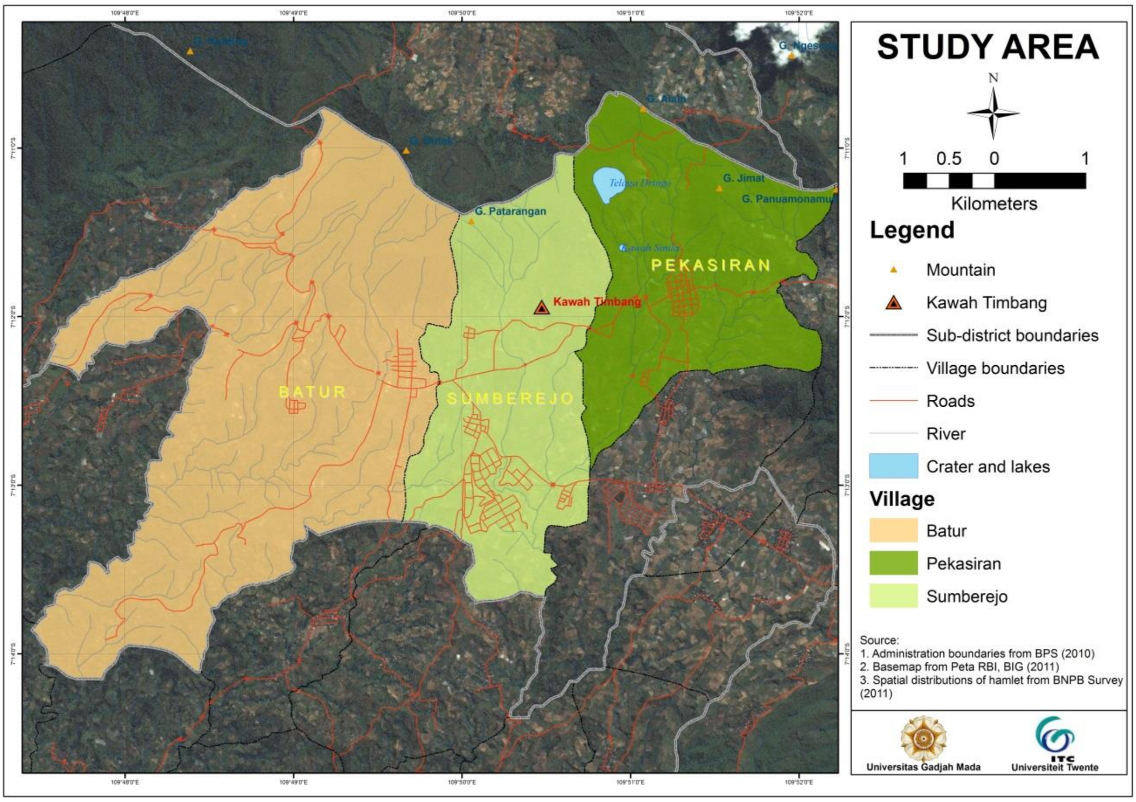


Figure 3.4 Study Area
(Source: Data processing)

Land-use of study area

The term of *land-use* is used to explain the uses of the land. Land-use both reflects and determines where economic activity takes place, and where and how communities develop. The concept of land-use is much related to human activities. Land-use affects the built environment in which individuals live, work and recreate. It also affects the quality of the natural environment, with impacts on air quality, water quality, water supply, and natural hazard vulnerability.

In the study area, the land use is categorized as rural land use. Most of the land uses are croplands (about 2088 ha). The other land uses in the study area are shrub land, plantation, settlements, grassland, and lake. The croplands are mostly. The details are listed in the Table 3.2:

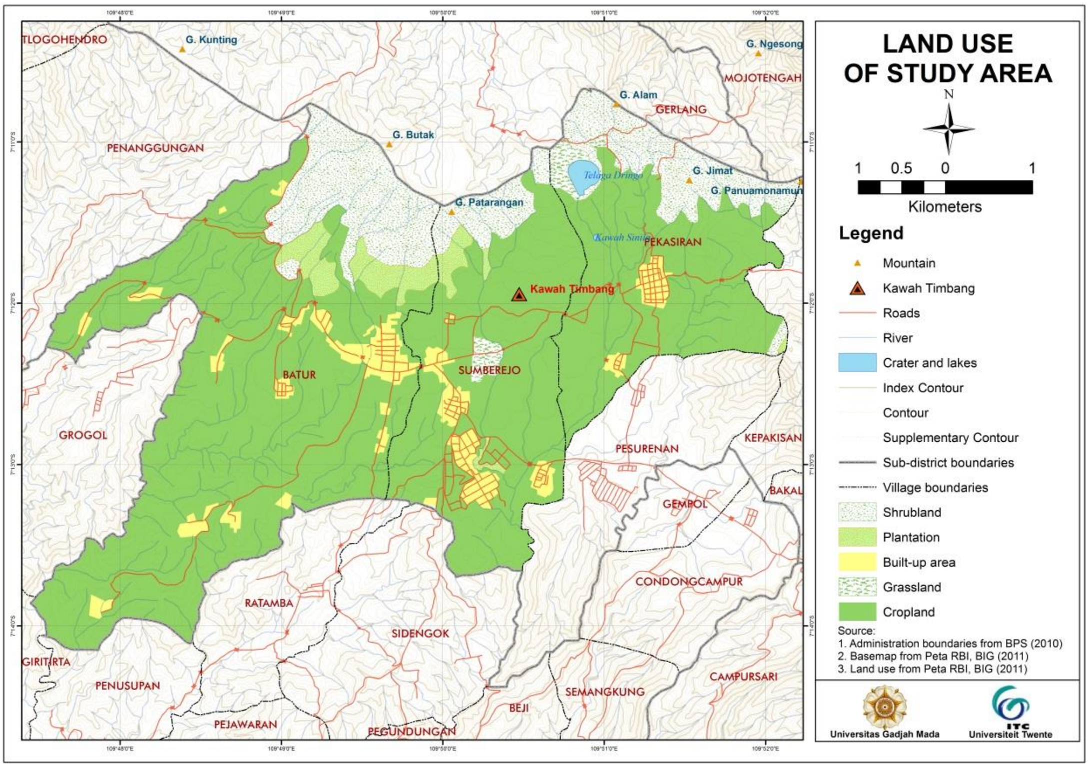


Figure 3.5 Land use of study area
(Source: Data processing)

Table 3.2 Land Use of Study Area in hectare

Land Use (ha)	Village		
	Batur	Pekasiran	Sumberejo
Lake	-	10	-
Shrubland	201	158	65
Plantation	65	1	23
Settlements	83	21	53
Grassland	-	18	14
Cropland	1,101	447	540
Grand Total	**1,450**	**655**	**695**

4. RESEARCH METHODOLOGY

This chapter describes about the research methodology which consists of three stages: pre-fieldwork, fieldwork, and post-fieldwork.

This research uses a case study approach as the main approach to answer the research problem. Case study is one of approach in human geography. The scope of human geography broadly differs from physical geography. The major focus of human geography is not only the physical landscape of the Earth, but the human activities which are linked with physical space. In this research, the research find the relation between CO_2 volcanic gas hazard as a physical aspect and human vulnerability in Dieng plateau.

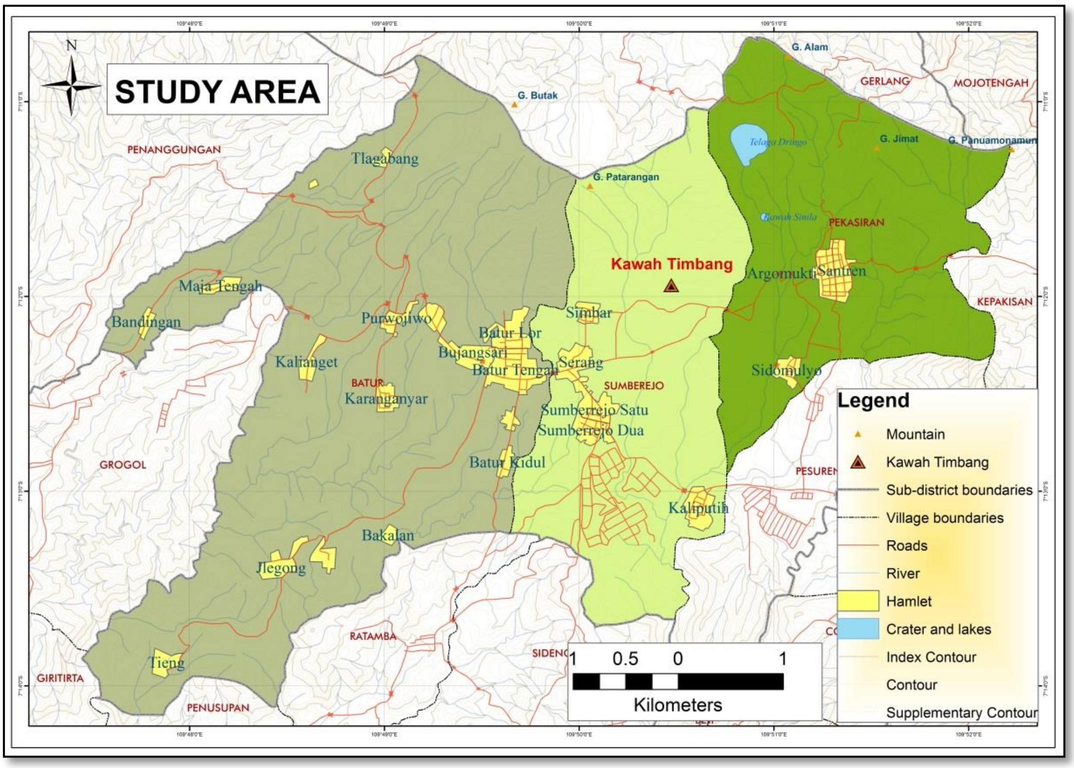


Figure 4.1 Spatial distributions of hamlet in the study area
(Source: Data processing)

As mentioned in the previous chapter, the sampling sites are the villages in the western part of Dieng plateau. The sampling sites were chosen by looking the existing hazard map (see sub-chapter 5.12) in order to represent the existing hazard zones. The villages which were chosen are Batur Village, Sumberrejo Village, and Pekasiran Village. The questionnaires and in-depth interview were conducted in household level and individual in these 3 villages.

The data were analyzed using both quantitative and qualitative approach. The questionnaires were analyzed by using frequency analysis, chi-square test and ordinal regression analysis using SPSS software, and also descriptive analysis. The results of in depth interview were analyzed and described qualitatively. The detail steps of this research will be described in the following sub-chapters.

The geographical unit of analysis in this research is hamlet. Hamlet is the smallest unit of society in Dieng. The research was carried out in 21 hamlets included in Batur Village, Sumberejo Village, and Pekasiran Village. As mentioned in the previous chapter, the hamlets are:

1. Batur Village: Bandingan, Maja Tengah, Kalianget, Purwojiwo, Bujangsari, Karanganyar, Batur Kidul, Batur Tengah, Batur Lor, Tlagabang, Jlegong, Bakalan, and Tieng
2. Sumberejo Village: Simbar, Serang, Sumberejo Satu, Sumberejo Dua, and Kaliputih
3. Pekasiran Village: Argomukti, Santren, and Sidomulyo

The unit of observation for questionnaire survey is household in the selected study area while the unit of observation for in depth interview is individual. The sampling methods and interview methods will be explained in the next sub-chapters.

Generally, the research stages in in this research consist of pre-fieldwork, fieldwork, and post-fieldwork.

4.1 Pre-fieldwork

First step in the pre-fieldwork phase is literature review. The literature reviews which have been done are related to the information about volcanic gases and main theories about vulnerability, risk perception, and coping capacity. The literatures were collected and reviewed from previous studies, books, scientific papers and reports, and also from media news. The literature review is important for determining the basic theory and methodology which used in this research. Other activities which have been done in pre-fieldwork phase are: obtaining research permission letter, designing questionnaire based on literature and preliminary observation, determining respondents and informants, mapping the study area for survey map. The detailed activities in pre-fieldwork phase are explained as follows:

4.1.1 Questionnaire Design

Questionnaire is needed in this research in order to acquire data about Dieng people, health and livelihood impacts due to gas hazard, perception, behavior, and their awareness of CO_2 volcanic gases. The questionnaire is also needed to acquire data about the community disaster management. The content of questionnaire must be readily understood and be about something that respondents are likely to have opinions (Flowerdew & Martin, 2005). Thus, it is important to make an understandable and practicable questionnaire in order to acquire best primary data. The stages of questionnaire survey in this research are shown in the Table 4.1 below:

Table 4.1 Questionnaire Stages

Activity	Specific tasks
Initial research idea	-Developing research objectives -Literature review/secondary data sources
Design of research	-Basic research design -Survey methodology: personal interview -Drafting questionnaire

(Table continued)

Sampling	-Decide sampling frame -Sampling technique: purposive techniques (quota sample)
Main fieldwork	-Interview and field observation
Processing/analysis of data	-Data transcription from questionnaire to computer -Production of tabulations
Results	-Results -Research report: summary in relation to research objectives

The content of questionnaire has to be in accordance with research questions. The content must also set out to measure something practicable and relevant to respondents (Flowerdew & Martin, 2005). In this research, the questionnaire was designed in order to give information about household background, vulnerability parameters, risk perception, coping capacity and community disaster management.

Since this research discuss about risk perception and how people deal with hazard (which links to attitude and behavior), the questionnaire consists of some parts with attitude and opinions measurement. Attitudes and opinions are generally considered to be the most difficult category of survey data to collect. This kind of data which derived from questionnaire survey must therefore be used with caution and must not be pushed too far (Flowerdew & Martin, 2005). Thus, it needs something that can "assess" this kind of data. Semantic differential scales are often used in the social survey. It consists of bi-polar scales, defined at each end by opposing pairs of descriptors. In this research, for example, this is the semantic scales in one of risk perception questions:

To what extent does the gas threaten your life?

☐*not serious at all* ☐ *not really serious* ☐*serious* ☐*very serious*

In general, how afraid are you of the gas?

☐*not afraid at all* ☐ *not really afraid* ☐*afraid* ☐*very afraid*

There are two questionnaires in this research. The first questionnaire consists of forty questions divided into four sections. The first section is the profile of respondents and the socio-economic characteristics (age, family member, monthly income, education, etc). Second section is about the health and livelihood impacts. The third section is about the disaster knowledge, experience, and risk perception. The fourth section is about the coping capacity. On the other hand, the second questionnaire consists of questions related to disaster management, such as: the institutions involved in Dieng, the role of each institutions, the availability of disaster equipment and services, etc.

4.1.2 Respondents Recruitment

This research used purposive techniques in recruiting respondents. Purposive technique is one of non-probability sampling methods. The most frequently used is quota sampling. Quota sampling is a method of stratified sampling in which selection of sample members within strata is non-random. The quota sampling will be applied to select the respondents. This kind of sampling involves interviewers (researcher) out to find respondents of particular types in accordance to research question so that the samples match with the target in the study area. Researcher set the minimum quota 20 respondents in each village. The quota was set and divided based on the hamlets in each village (see Table 4.1).

Table 4.1 Set Quota Samples

No	Village	Hamlet	Hazard Zone 2011	Set
1	Batur	Bandingan	-	2
2		Maja Tengah	-	2
3		Kalianget	Zone II	2
4		Purwojiwo	Zone II	2
5		Bujangsari	Zone II	2
6		Karanganyar	-	2
7		Batur Kidul	Zone II	2

(Table continued)

No	Village	Hamlet	Hazard Zone 2011	Set
8		Batur Tengah	Zone II	2
9		Batur Lor	Zone II	2
10		Telagabang	Zone II	2
11		Jlegong	-	2
12		Bakalan	-	2
13		Tieng	-	2
14	Sumberejo	Simbar	Zone III	4
15		Serang	Zone III and Zone II	4
16		Sumberrejo Lor	Zone III and Zone II	4
17		Sumberrejo Kidul	Zone III and Zone II	4
18		Kaliputih	Zone III and Zone II	4
19	Pekasiran	Sidomulyo	Zone III and Zone II	7
20		Argomukti	Zone II	7
21		Santren	Zone II	7
Overall for 21 hamlets				67

4.1.3 Informants recruitment

There are different ways to approach potential informants. In this research, the recruitment of informant was done by using *Gatekeepers* and *Snowballing* techniques. Gatekeepers are individuals in an organization that have the power to grant or withhold access to people or situations for the purposes of research (Flowerdew & Martin, 2005). In this research, researcher will contact the volcanic post officer in Dieng, hamlet heads and elder people who have experience in 1979 disaster to gain more information about the hazard. In addition, researcher also asked people using *snowballing* technique. *Snowballing* technique is a technique which one contact help researcher to recruit another contact, who is purposively chosen because of their knowledge related to research. In this research, the snowballing will be conducted by asking the key informants about the recommended informant for the next interview. The interviews were finished after all the information gathered.

4.2 Fieldwork

The fieldwork was carried out from November 2014-January 2015. The fieldwork was done in order to obtain primary data using questionnaire, in depth interview, and field observations. The data collected during pre-fieldwork and fieldwork is shown in the table below:

Table 4.2 Data Collection

No	Theme	Data Requirement	Data Collected
1	CO_2 susceptible areas identification	1. Spatial distribution of CO_2 gas events 2. Concentration of CO_2 each locations 3. Classification of $CO_{2\ \%}$ volume based on health effects 4. CO_2 characteristics	1. Measurement of CO_2 from mofettes and soil gas in Western Dieng from BBPTKG Yogyakarta year 1999-2001 (hardcopy, has been input into .shp format) 2. Gas composition and gas flux in Western Dieng from BBPTKG Yogyakarta year 1999-2001 (in table format) 3. CO_2 spatial distributions from ESDM ministry year 2000-2007 (digitized) 4. Health effects classification from literatures 5. Volcanic hazard map of Dieng Volcano year 2011 from ESDM ministry (digitized) 6. CO_2 spatial distributions from ESDM ministry year 2011
2	Basemap and study area characteristics	1. Base map of Dieng 2. Spatial distributions of crater and lakes 3. Geological settings of Dieng Plateau 4. Spatial distributions of hamlet (*dusun*) 5. Demography profiles 6. Landuse of Dieng	1. Base map and administration boundaries from Peta Rupa Bumi Indonesia 2010 (from Geospatial Agency and Bureau of Statistics) 2. Spatial distributions of crater and lakes from survey plotting 3. Geological map of Banjarnegara-Pekalongan scale

(Table continued)

No	Theme	Data Requirement	Data Collected
		Plateau from imageries	1:100.000 from Geological Research and Development Center, Bandung 4. Spatial distributions of hamlets from BNPB survey year 2011 5. Villages profiles from PODES year 2008, Kecamatan Batur Dalam Angka 2014 (from Bureau of Statistics) and BNPB survey 2011 6. Landsat (from USGS) and Quickbird imageries of Banjarnegara area (from BPN)
2	Human Vulnerability	1. Information about location of activities and home 2. Information about casualties and health experience related to CO_2 3. Information about livelihood and resources	1. Information about Timbang earthquake chronology year 2011 and 2013 2. Information about refugee list year 2011 (Dusun Simbar and Dusun Serang) and 2013 3. Information about type of diseases during the evacuation period on 2011 4. Primary data from questionnaire and in-depth interview
3.	Risk perception	1. Risk perception related to hazard 2. Risk perception related to livelihood	1. Secondary data from news (text and videos) 2. Primary data from questionnaire and in-depth interview
4.	Coping capacity and community disaster management	1. People's strategy towards CO_2 volcanic gases 2. Community disaster management	1. Primary data from questionnaire and in-depth interview

4.2.1 Questionnaire Survey

The questionnaire survey was conducted by asking respondents at twenty one hamlets in the study area. Instead of giving them the questionnaire, the researcher have asked the questions and filled the respondents' answers directly to the questionnaire. The respondents' locations were plotted using PDFMaps application on mobile device. During the questionnaire survey, the researcher was helped and guided by local people when asking and searching the next respondents.

Figure 4.2 Filling the questionnaire while asking respondents
(Source: Researcher's documentation)

Researcher successfully interviewed 70 respondents in the study area. The achieved quota samples which have been interviewed shown in Table 4.3 below:

Table 4.3 Achieved Quota Samples

No	Village	Hamlet	Hazard Zone 2011	Achieved
1	Batur	Bandingan	-	2
2		Maja Tengah	-	2
3		Kalianget	Zone II	2
4		Purwojiwo	Zone II	2
5		Bujangsari	Zone II	2

(Table continued)

No	Village	Hamlet	Hazard Zone 2011	Achieved
6		Karanganyar	-	2
7		Batur Kidul	Zone II	2
8		Batur Tengah	Zone II	3
9		Batur Lor	Zone II	2
10		Telagabang	Zone II	3
11		Jlegong	-	2
12		Bakalan	-	2
13		Tieng	-	2
14	Sumberejo	Simbar	Zone III	4
15		Serang	Zone III and Zone II	6
16		Sumberrejo Lor	Zone III and Zone II	4
17		Sumberrejo Kidul	Zone III and Zone II	4
18		Kaliputih	Zone III and Zone II	4
19	Pekasiran	Sidomulyo	Zone III and Zone II	7
20		Argomukti	Zone II	6
21		Santren	Zone II	7
Overall for 21 hamlets				70

4.2.2 In-depth interview

Beside questionnaire, in depth interview is one of the methods in this research. In-depth interview can hopefully help develop the questionnaire result in answering research questions. Interview method is generally unstructured or semi-structured. The aim of an interview is not to be representative, but to understand how individual people experience and make sense of their lives (Flowerdew & Martin, 2005).

In depth interview in this research was a usual in-depth interview and a go-along interview. The usual in-depth interviews were done for disaster management interviews, while the go-along interviews were done for human vulnerability and coping capacity interviews. Basically, the “Go-Along” interview is a combination between field observation and a usual “sit-down” interview. The “Go-Along” interview was firstly developed by sociologist, Margarethe Kusenbach (2003). The go-along seems to be more beneficial comparing to usual interview because it can derive “spatial experience” from informant. The go-along interview was done in the most affected hamlets (nearest Timbang).

The researcher successfully interviewed fifteen informants which has a special understanding of Dieng volcanic gas disaster. The informants consist of Sinila 1979 victims, hamlet heads, former Dieng Volcanology Staff, Dieng Volcanology Staff, BAGANA NU, and KOKAM Muhammadiyah Sumberrejo (community disaster NGOs in the study area).

4.2.3 Participatory GIS

In this research, PGIS was used in determining the hazard prone areas based on people’s knowledge, people’s disaster experience, and people’s suggestions for disaster risk management. The tools which have been used in PGIS are: survey maps in PDF file, mobile device, GPS, and notes. The respondents of the research were asked to show and plot the important locations on researcher’s mobile device (with PDFMaps and GPS) related to hazardous areas, their spatial disaster experiences, and their suggestions for disaster risk management.

4.3 Post-fieldwork

The post-fieldwork phase consists of description of the pre-fieldwork and fieldwork results, discussions and analysis. The first discussion is about the volcanic CO_2 hazard in Dieng. The next discussions are about the socio-economic profiles of respondents, the vulnerability during non-eruptive and eruptive periods, risk perception, and coping capacity.

4.3.1 Volcanic CO_2 hazard in Dieng

Before study the human vulnerability and coping capacity within Dieng plateau, it is needed to map specific hazardous locations. The spatial distributions of CO_2 should be known in order to know the hazardous area in Dieng plateau. The spatial distributions of CO_2 is in the form of a dots map showing the location and the gas concentration values in several years. The dots map then should be classified based on the concentration and health effects. The health effects are usually related to the exposure time. But, since in Dieng there is no available data about the duration of exposure time, the classification will only be based on the range of % CO_2 concentration volume. This classification shows the potential vulnerability of the area based on the CO_2 concentrations. After classifying the CO_2 susceptibility in dots map, the dots map can be symbolized based on the classification in order to obtain the spatial extent of vulnerable area each location.

4.3.2 Human Vulnerability Assessment

The human vulnerability assessment in this research will be based on previous framework of human vulnerability (Dibben & Chester, 1999). The human vulnerability identification is quite different with other vulnerability assessment because this research will identify the human vulnerability and the root cause spatially and descriptively. First, this research will describe the socio-economic profiles of respondents using frequency analysis. Then, the socio – economic profiles will be discussed. After discussing the socio-economic characteristics, the human vulnerability will be discussed by looking the disaster impacts which consists of health and livelihood impacts.

4.3.3 Risk Perception and Coping Capacity

In this research, risk perception was identified using various measures which consist of: perception of *risk likelihood*, perception of *threaten life*, perception of *affect life quality*, perception of *financial loss*, and the perception of *dread*. Those risk perception items were adopted from Ho, Shaw, Lin, & Chiu's (2008) previous study about risk perception. In this research, the risk perception will be discussed using statistical analysis. Techniques which used to discuss risk perception in this research are descriptive statistic and Chi-square analysis. The relationship between vulnerability and risk perception will also be analyzed. The data was examined by using cross-tabulation and Chi-square test, and ordinal regression analysis.

The coping capacity will be analyzed qualitatively by categorizing the people's strategy or mitigation measures due to CO_2 volcanic gases. The coping capacity consists of physical, economic, and social aspects. This discussion also discuss about the residential mobility and community disaster management as a part of coping capacity.

4.3.4 Research's concluding remarks

After all the research questions answered, the research will be concluded in the concluding remarks chapter. The human vulnerability, risk perception, and coping capacity will be linked. Recommendations for community and government will be obtained in this part of discussion.

5. RESULTS AND DISCUSSIONS

5.1 CO_2 hazard mapping

This sub-chapter discusses about the volcanic CO_2 characteristics and spatial distributions in Dieng, existing volcanic hazard zone map, hazard prone area based on PGIS, and potential vulnerability map based on health effects classifications.

5.1.1 Volcanic CO_2 characteristics in Dieng

Geomagnetic and spatial distributions of CO_2

As discussed in the previous chapter, volcanic CO_2 gases are influenced by the geological setting of the area. In addition, the geological setting is associated with geophysical factors especially geomagnetic values. Geomagnetic values are the magnetic field strengths which are usually measured in *nanotesla* (nT). The magnetic fields of geological bodies are superimposed on the background of the Earth's main field (Milsom, 2003). The magnitude and direction of the magnetic fields influence both the magnitudes and shape of local anomalies. The shape of magnetic anomaly varies with the dip of the Earth's field, as well as with the variations of its magnetic direction. This magnetic anomaly can identify the existing of geological structure like faults, fissures, or lineaments, where the volcanic CO_2 can effuse along those structures. Thus, it is important to know the magnetic anomaly in Dieng which associated with the geological structure, in order to know the CO_2 hazard potential areas (excluding the meteorological factors).

According to Volcanological Survey of Indonesia, the regional magnetic value of Dieng Complex is 45033.7 nT. Based on Residual Magnetic Anomalies Map on Dieng Complex, there are two major lineaments which show contrast magnetic anomalies: North West (NW) – South East (SE) magnetic lineament and South West (SW) – North East (NE) magnetic lineament. Figure 5.1 below shows the magnetic anomalies range between -1614 until 1997.9 nT. The magnetic anomalies value can be divided into three classes, which are:

a. Low magnetic anomalies (green – dark yellow) which have value less than -200 nT. It is interpreted as a non-magnetical rock, which is a deflection of volcanic rock which highly weathered. It is also interpreted as area which associated with geothermal sources.

b. Moderate magnetic anomalies (dark yellow – light blue) which have value between -200 until 400 nT. It is interpreted as andesite which has weathered moderately.

c. High magnetic anomalies (light blue – dark blue) which have value more than 400 nT. It is interpreted as an area which has poorly weathered (the rocks are still fresh), the intrusion rocks, or volcanic rocks which dominated by lava.

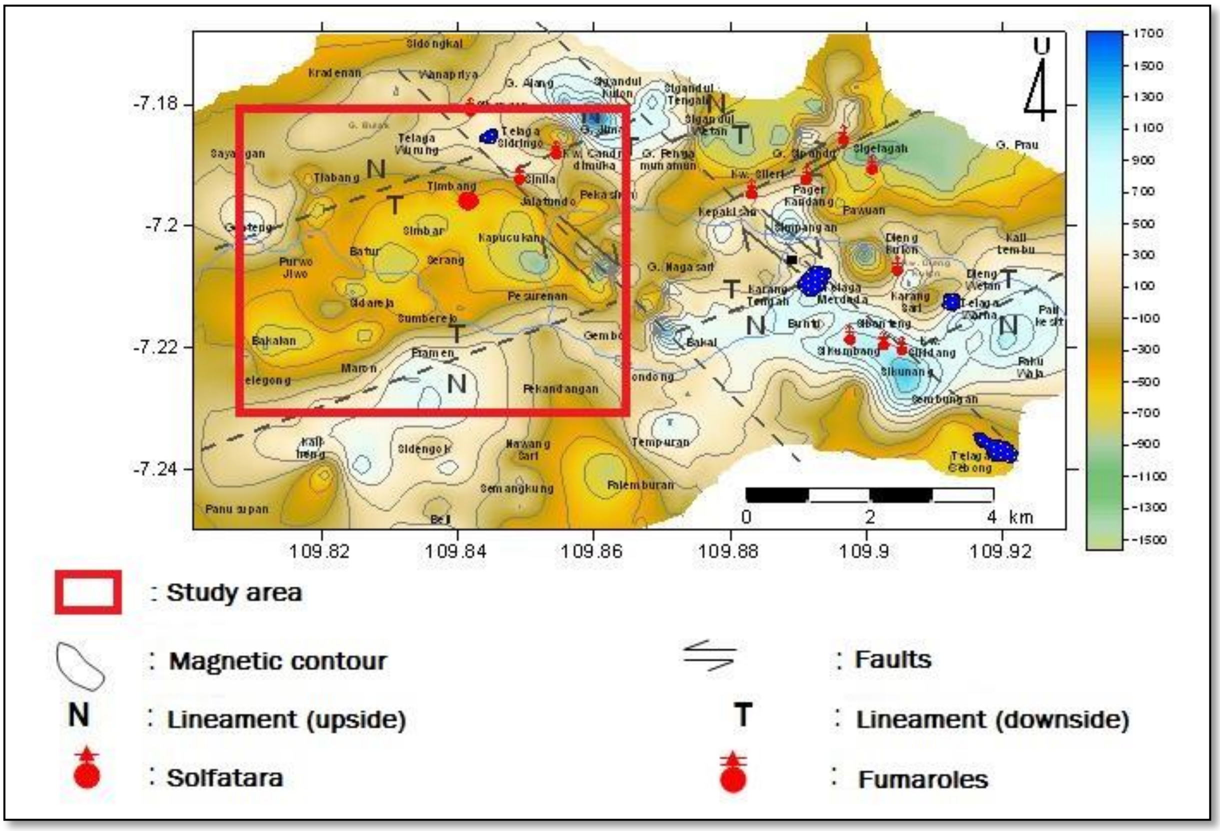


Figure 5.1 Residual Magnetic Anomalies Map in Dieng Complex (Source: VSI, 2014)

The magnetic lineaments are interpreted as an indication of the existing of faults. The SW-NE lineament is older than NW-SE lineament. The existing of solfatara, fumaroles, and CO_2 moffettes are highly influenced by these structures. From the figure above, the study area has low magnetic anomalies, which has highly weathered rocks and interpreted as area which associated with geothermal sources. The areas included are Simbar, Serang, Pesurenan, Pekasiran, Timbang, Sinila, Candradimuka. The CO_2 can easily effuse to the surface if there is a crack or fissure. Thus, the study area may have many CO_2 hazard potential areas.

CO_2 Gas Concentrations

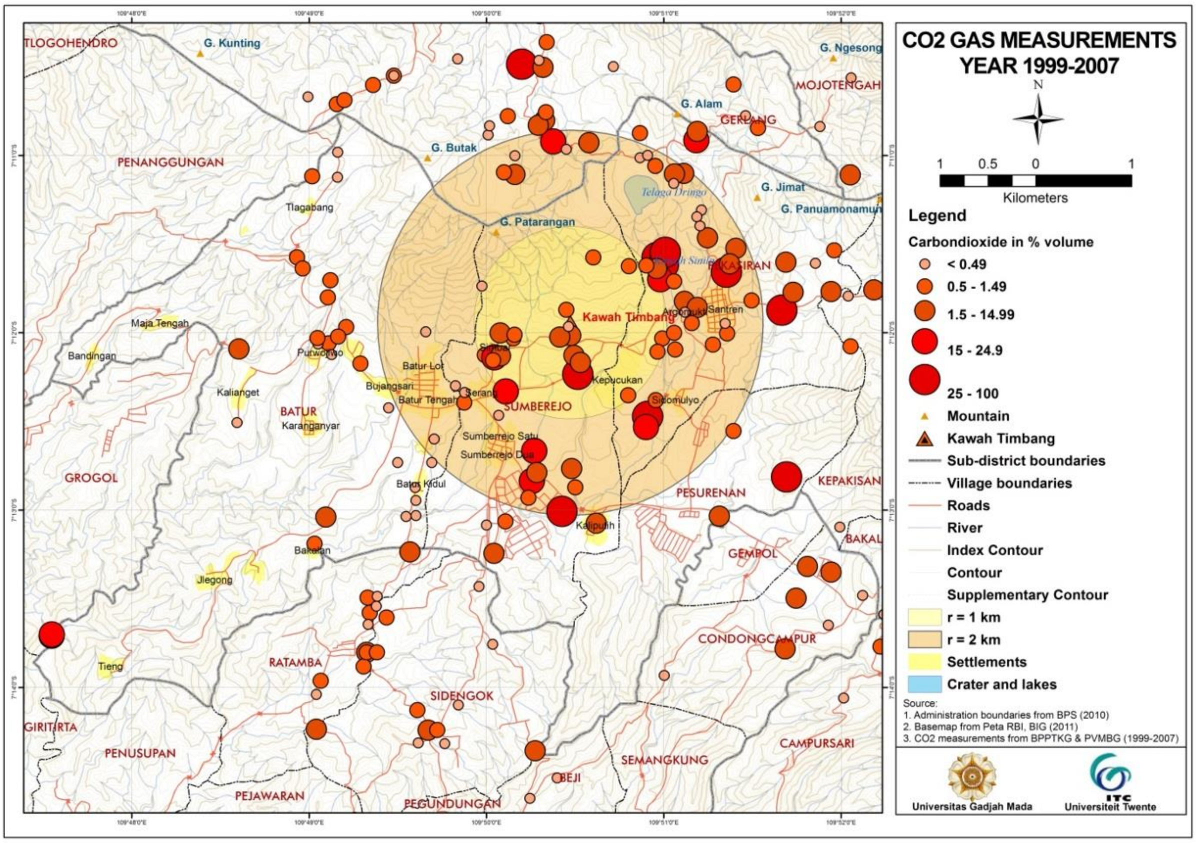


Figure 5.2 Spatial distributions of CO_2 measurements in 1999-2007 periods
(Source: Data processing)

There were two volcanic gas measurements which have been conducted in Dieng complex. The map in the Figure 5.2 above shows the spatial distributions of CO_2 gas in years (from 1999 to 2007). The gas sampling measurements method in the period of 1999-2001 were conducted using Giggenbach method (Humaida et al., 2002). The samples were collected in flasks through titanium tubes deeply inserted into the gas vent. The gas samples were determined by gas chromatography and standard analytical procedures. The 2000-2007 measurements were conducted in the surrounding of craters, fumaroles, solfataras, mud pools, and along the cracks and fault zones. The concentrations vary with the range between 0.01-100 in % volume. Based on Figure 5.2, hamlets which have high concentrations are mostly in < 2 km radius from Timbang crater, such as Simbar, Serang, Sumberejo, Kaliputih, Sidomulyo, Argomukti and Santren.

CO_2 Gas Flux

Beside gas concentration, CO_2 can be identified by measuring the gas flux. Gas flux is one of important factor of volcanic gas effusion. The gas flux is the amount of gas per unit time per unit area. The toxicity of CO_2 gas depends on the amount of inhalation (Humaida et al., 2002). If there is high concentration of gas, but it has small flux, it may less affect human.

Based on Humaida et al. (2002) research , total CO_2 gas flux in western Dieng plateau was estimated 11.564.648.05 gr/hour or 277.44 tons/day. The highest gas flux was in Candradimuka crater, but the highest concentration was in Timbang crater. The table below is the result of gas flux measurement details:

Table 5.1 CO_2 gas flux of craters in western Dieng plateau

No	Area of Gas Sources	Gas Velocity (m/s)	Gas Concentration (%)	Gas Flux Area (gr/hour)
1	Timbang	0.5	**80.13**	2,225,170.30
2	Candradimuka	1	56.09	**4,672,764.00**
3	Sinila	0.5	53.36	237,166.00

5.1.2 Dieng Volcanic Hazard Zone

There is an existing hazard zone map from Center for Volcanology and Hazard Mitigation (PVMBG). This hazard map was made based on the previous disaster occurrences. The PVMBG will update the map if there is new affected area, unless the map will stay the same. This map below (Figure 5.3) is the hazard zone map based on past disasters (until 2011):

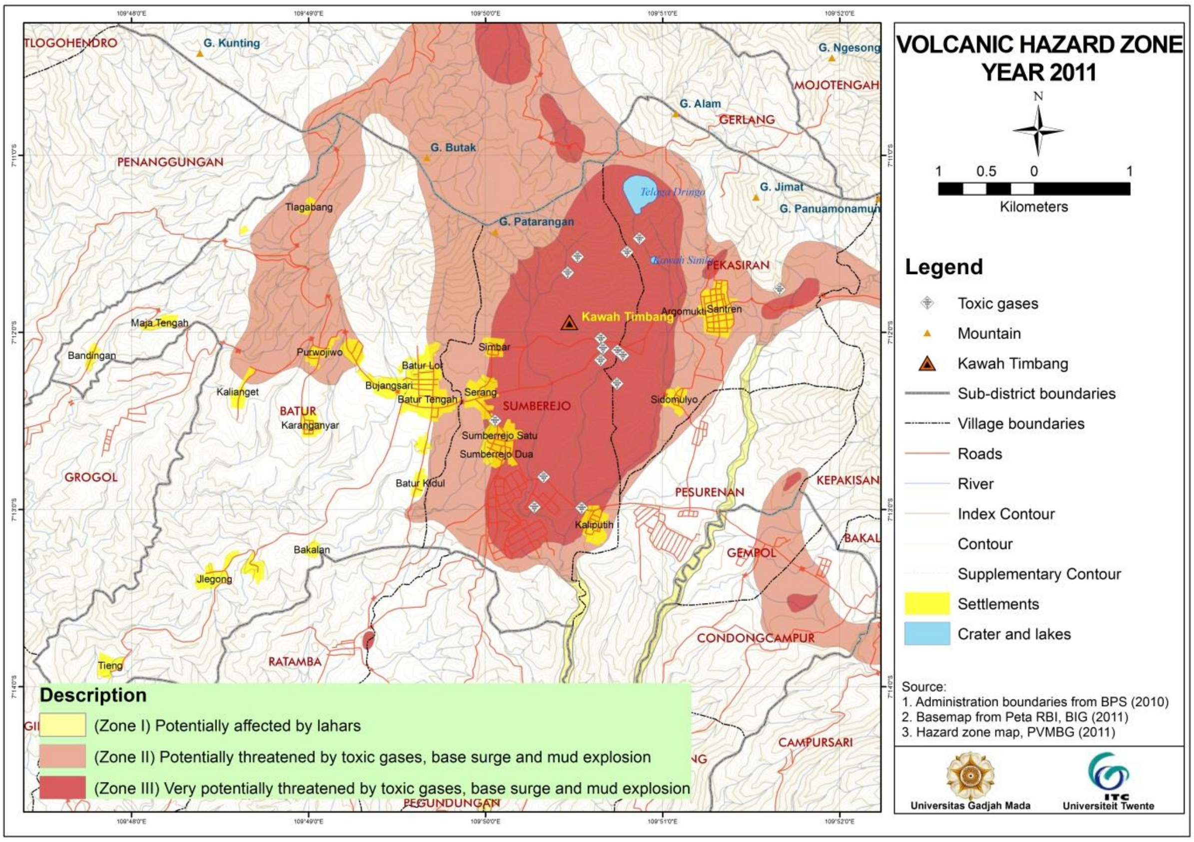


Figure 5.3 Dieng Volcanic Hazard Zone year 2011
(Source: hazard zone from PVMBG)

The most susceptible areas based on hazard map is Sumberejo village, which very potentially threatened by toxic gas, base surge, and mud explosion. All hamlets in Sumberejo village are covered with the Zone III. While other village which affected are Pekasiran and some part of Batur. Pekasiran and Batur are on the Zone II, which potentially threatened by toxic gases, base surge, and mud explosion. In fact, the geographical extent of hazardous areas is not as wide as the hazard zone map. In addition, the hazard zone map is still debatable; the method to delineate the zone is unknown. For example, there is Zone I, zone which potentially affected by lahars. But, based on Dieng eruption histories, Dieng has almost never erupted magmatic eruption but dominantly a phreatic eruption. Thus it is important to check and re-analyze this hazard zone map so that it can be revised and give valid information to the community.

Based on research fieldwork and interview with Dieng Volcanological Center, the extent of the toxic gas spread 1 km to the south of Timbang crater (along Kalisat, Kepucukan, and Kaliputih) (see Figure 5.4).

5.1.3 Volcanic gas hazard prone areas using PGIS

This research uses participatory GIS methods to integrate the local knowledge with geographical information system tools. It is important because the local people know the very specific spatial information about hazard prone areas in a way that other maps cannot. The hazard-prone specific spatial information that local people know is usually based on their local knowledge and disaster experiences. The spatial distribution of hazard prone areas can be shown at the Figure 5.4.

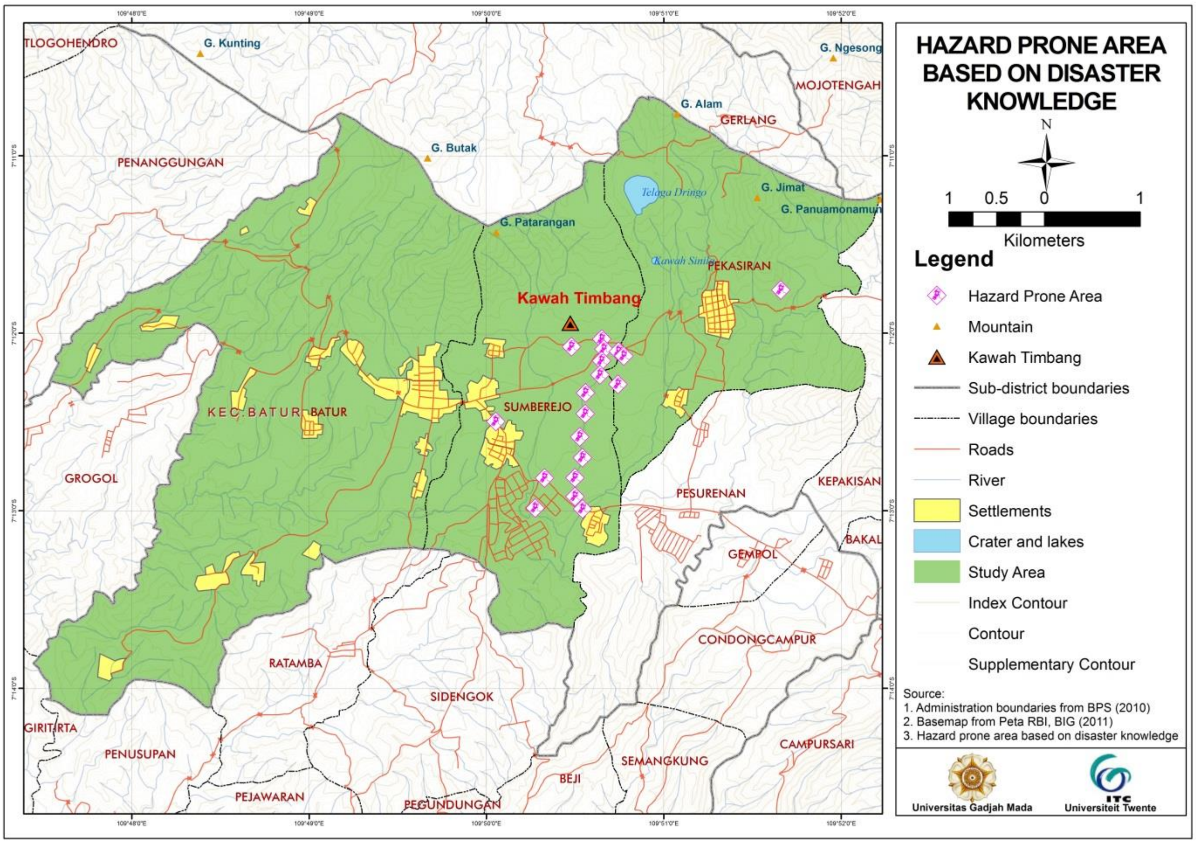


Figure 5.4 Volcanic gas hazard prone areas based on PGIS
(Source: Data processing)

There are some places which are hazardous to volcanic gases. The hazard prone areas were determined by respondents based on their knowledge about geomorphological setting and also the past accidents which related to CO_2 toxic gases. Local people know that CO_2 gases can be accumulated in a morphological depression or low-lying areas, such as Timbang and Kalisat downslopes, and also Kaliputih river. In addition, local people also know the past accidents which related to CO_2 toxic gases, such as: 1. a researcher died because of asphyxia in Gua Jimat (small depression in the eastern of Pekasiran) 2. a man died near Kalisat. Thus, they determined Gua Jimat and Kalisat as hazardous areas based on those accidents.

Based on Figure 5.4, the hazard prone areas are located especially along Kaliputih river, the southern part of Timbang. Farmers who work near Kaliputih river have known that the CO_2 gas usually flow in the dawn and in the evening. The CO_2 gases are usually mixed with water (H_2O) so that the gas can be "*visible*" in the form of fog. When there is sunlight, the fog will disappear. Beside Kaliputih river, the hazard prone areas are located in the soccerfield near Kalisat, in *Proyek (*also near Kalisat), Gua Jimat (the eastern of Pekasiran), and in front of Sumberrejo Satu hamlet house (near Sumberrejo main roads).

5.1.4 CO_2 potential vulnerability based on human health effects

Based on human health effects, the potential human vulnerability was classified into 4 classes: *lowly vulnerable to asphyxia, moderately vulnerable to asphyxia, highly vulnerable to asphyxia, and very highly vulnerable to asphyxia*. Table 5.2 shows the classification of human responses and the potential vulnerability classes. In Figure 5.5, it can be seen that moderate-high classes are spreading in eastern part of study area, which cover Sumberrejo and Pekasiran village. The most susceptible areas are located in Sinila crater, northern part of Pekasiran, Sidomulyo, and Kaliputih.

Table 5.2 Potential human vulnerability classes based on human health effects

Concentration of carbon dioxide (%)	Human Responses	Vulnerability
< 0.5 %	Safe and tolerable	No hazard at any time
0.5 - 1.49 %	Respiratory rate increase 37%	Lowly vulnerable to asphyxia
1.5 – 14.99 %	Brain blood flow, dizziness, confusion, dyspnea, headache, Severe HA, dizziness, confusion, dyspnea, sweating, dim vision, hypertension, & loss of consciousness	Moderately vulnerable to asphyxia
15-24.99 %	Unbearable dyspnea, followed by vomiting, disorientation,	Highly vulnerable to asphyxia
> 25 %	Soon causes unconsciousness, death occurs by lack of oxygen (asphyxia)	Very highly vulnerable to asphyxia

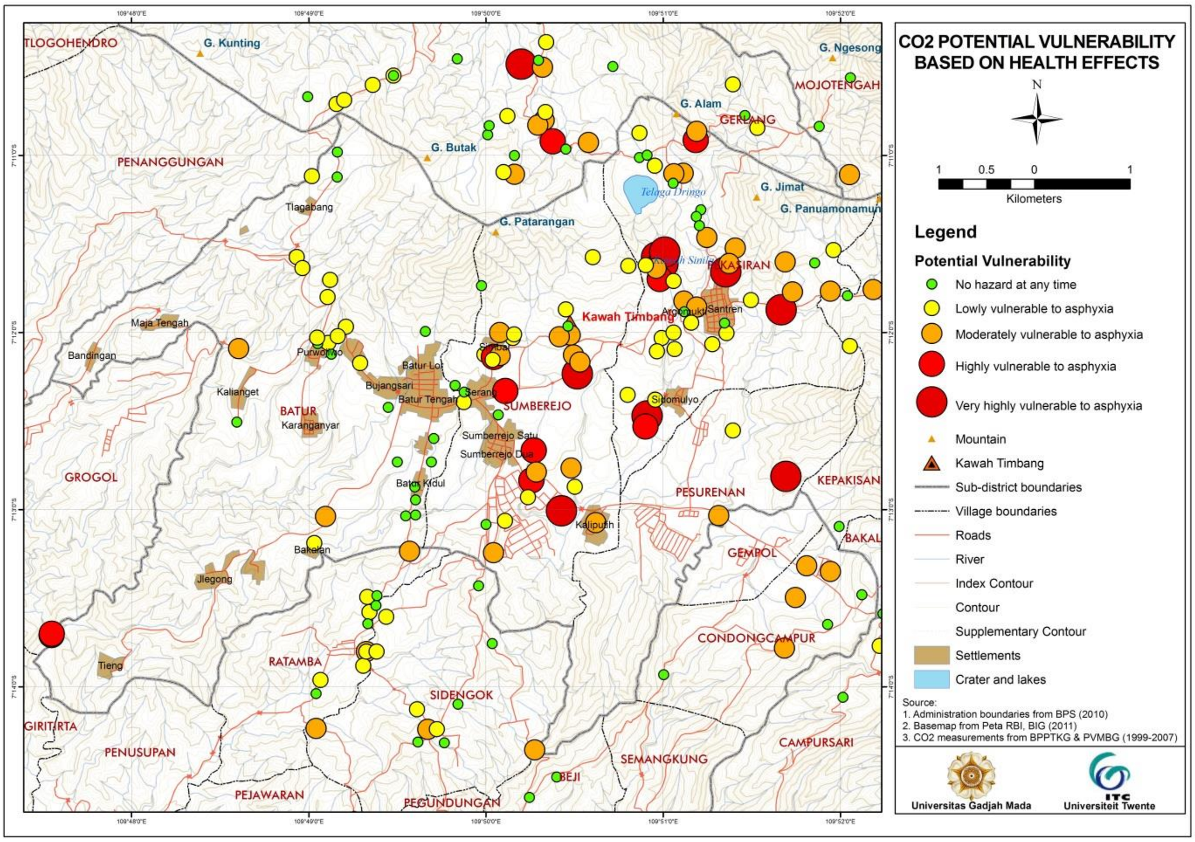


Figure 5.5 Potential human vulnerability map based on health effects

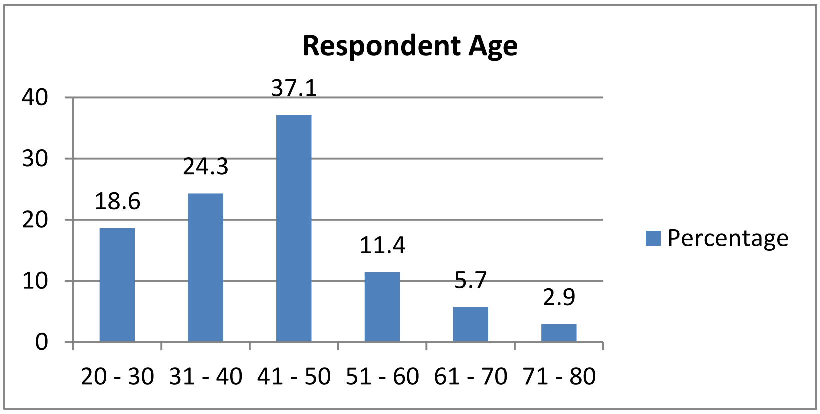
5.2 Human Vulnerability

This sub-chapter discusses about the socio-economic characteristics of respondents, Timbang disaster impacts on health and livelihood, and the discussion about respondents location and disaster impact experiences.

5.2.1 Socio-economic characteristics

According to Cardona (2001) (cited in Bankoff, Frerks, & Hilhorst, 2004), vulnerability originates in socio-economic fragility. Vulnerability can be disadvantageous conditions and relative weakness related to social and economic factors. Thus, this research uses socio-economic characteristics as parameters assumed to have influence on human vulnerability. Socio-economic characteristics in this research consist of: age, education, occupations, monthly income, house ownership, agriculture land ownership, livestock ownership, vehicle ownership, and residential origins.

Age

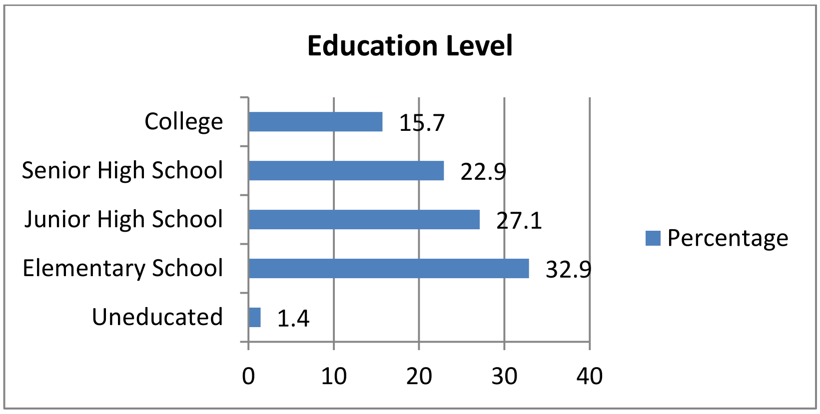


Graph 5.1 Age of Respondent

The range of respondent age in the study area is between 20-75 years old. The respondents' age were classified into some classes. The respondents are mostly aged between 41-50 years old with the highest percentage 37.1 %. While the youngest 20-30 years old is about 18.6 % of total respondents. Some respondents are also elder people, with the 7.9 % of 71-80 years old.

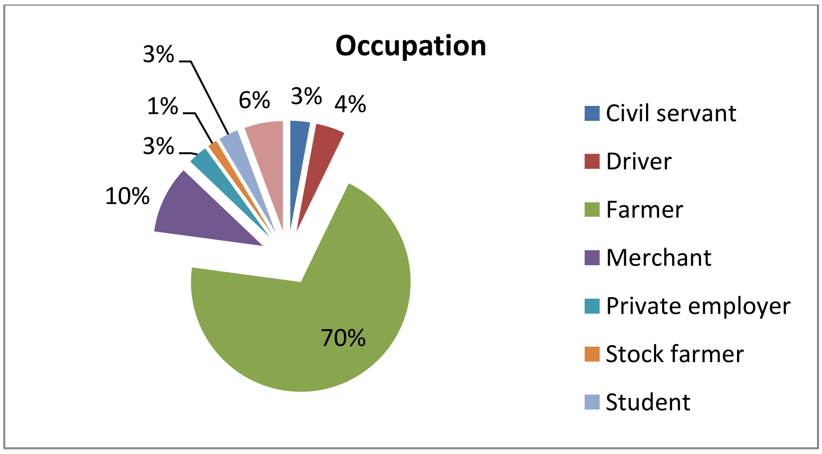
Education Level

The education level among respondents is almost equally distributed. But, they mostly have low education level. The majority of respondents were elementary school with 32.9 %. While respondents who have junior high school and senior high school degrees are 27.1 % and 22.9 %. Respondents who have bachelor degree are only 15.7%. Based on fieldwork and observations, rural people in Dieng tend to work as farmers which do not require a high education level.



Graph 5.2 Education Level

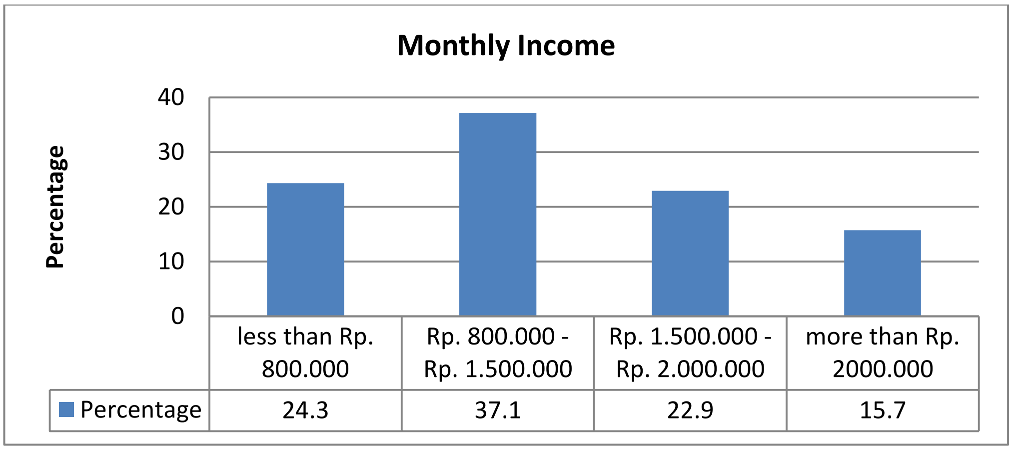
Occupation



Graph 5.3 Occupation

Respondents are mostly farmers with 70 % proportion of total respondents. The second highest percentage of occupation is Merchant with 10 %, Teacher with 6 %, and with Driver 4 % proportion. Because Dieng is a rural area with volcanic fertile soil, agriculture has been the main economic activities which support the livelihood of Dieng people.

Monthly Income



Graph 5.4 Monthly Income

The monthly income percentage among respondents is almost equally distributed. Most of households (37.1%) have income between Rp. 800.000 – Rp. 1.500.000. While the respondents who have income only less than Rp. 800.000 is about 24.3%. Thus, it can be said that the majority of households have a quite low income.

Property ownership

The property ownership characteristics are important to know in order to identify the resources that may increase vulnerability. The property ownership characteristics can be seen in the Table 5.3 below:

Table 5.3 Ownership

Characteristics	**Type**	**Percentage**
House Ownership	Owner	100%
Agricultural Land Ownership	None	37%
	< 1 ha	36%
	1-2 ha	19%

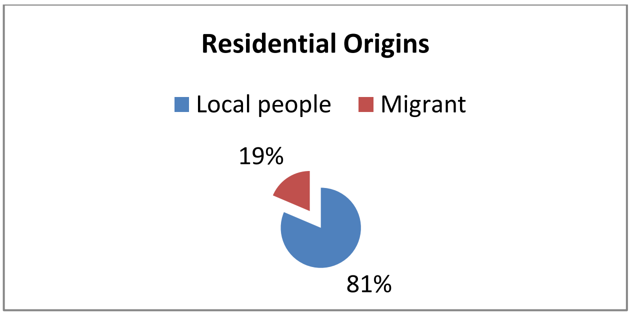
(Table continued)

	>2 ha	9%
Livestock Ownership	None	74%
	Poultry	14%
	Goat	6%
	Cow	6%
Vehicle Ownership	None	4%
	Motorcycle	69%
	Car	27%

In terms of house ownership, all of respondents have their own house. In terms of agricultural land ownership, most of respondents have no agricultural land (37%) while others have less than 1 hectare (36%). It is because farmers do not always have their own land; mostly they are workers for some land owners. When disaster occurs, some land owners may have agricultural losses and the workers lose their jobs for a while. In terms of livestock, respondents mostly do not have livestock (74%). While in some hamlets, like in Simbar, Serang, and Sumberrejo Dua, respondents have poultry, goat and cow (26% in total). Livestock could be affected by gas. According a respondent in Serang hamlet, when disaster 2013 occurred, their chickens perished because of the CO_2 gas.

In terms of vehicle ownership, most of respondents have a motorcycle in their house (69%). While some of respondents have car (27%). The availability of vehicle can improve evacuation process when disaster occurs, especially for people who live near Timbang. People who do not have car usually follow their neighbors who have cars.

Residential Origins



Graph 5.5 Residential Origins

In terms of residential origins, most of respondents (81%) were born in their own village. While some others are migrants originates from the surrounding villages in Dieng (19%).

In summary, the socio-economic characteristics that influence human vulnerability based on information gathered during the fieldwork are shown and summarized in the table below:

Table 5.4 Socio-economic indicators influencing human vulnerability

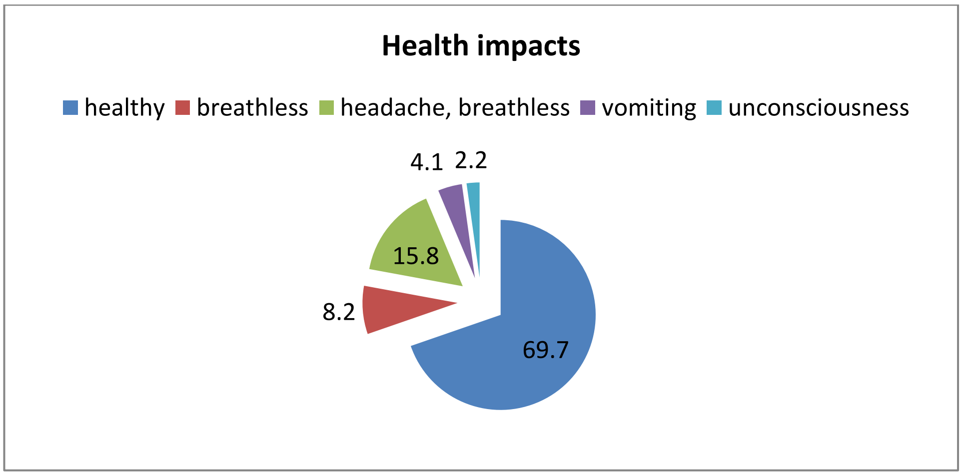
Socio-economic characteristics	**Description**	**Increases (+) or decreases (-) human vulnerability**
Age	• Age is related to the ability to move during the evacuation • The elder people and children need some assistance during evacuation process	Elder people (+) Children (+)
Education Level	• The education level does not directly influence the vulnerability because they have disaster experiences.	The low educated and the high educated are having the same potential vulnerability (+)
Occupation	• People who works as farmer are more vulnerable to volcanic gases • People who works as driver are also vulnerable, especially when disaster occur (there are no vegetable commodities to distribute, the accessibility were usually closed)	Farmer (+) Driver (+) Formal employer (-)
Income	• People who have low income and daily income are more vulnerable because they cannot afford the living cost when disaster occurs/when they are evacuated. • People who have high income are less vulnerable because they usually have savings and extra money to survive when disaster occurs	Low income (+) Low and daily income (+) High income (-)

(Table continued)

Property Ownership	• People who have agricultural land near Timbang are more vulnerable to agricultural losses • People who have livestock near Timbang are more vulnerable to economic losses • People who have vehicle in their house are less vulnerable because they have capacity to move out/evacuate	Land owner near Timbang (+) Livestock owner near Timbang (+) Vehicle owner (-)
Residential Origins	• The residential origins/length of stay can determine the social network. People who stay more than 25 years have a place attachment and strong relationship with the neighbors. The social network is good (related to community disaster management) • The local people have more disaster experiences than the migrants	Local people (-) Migrants (+)

5.2.2 Disaster Impacts on Human Health and Livelihood

Human Health



Graph 5.6 Health impacts

Based on fieldwork, the human health impacts of volcanic gases were identified. Most of respondents (69.7%) said that they were healthy every day, even when Timbang disaster occurs. The volcanic CO_2 gases were not really affected their health, except the smell of sulphur gases (H_2S and SO_2). The CO_2

concentrations under 0.5 % in air are safe and tolerable. But, some of the respondents in Batur and Sumberrejo village said that they experienced headache and breathless or accelerated breathing (15.8%). It means that they might be affected by the gas under 5% concentrations. The gas effects were also more hazardous during the night. As one informant from Simbar, Pak Metsuroso (56 years old) said:

> "*During the sleep at night, we were not able to cover our nose with the mask, so that we breathe the gases during our sleeps. When we woke up, we often felt breathless after that.*"

Most of respondents who experienced these symptoms are located in Simbar, Serang, Sumberrejo and Batur Tengah in radius < 2 km from Timbang crater (see Figure 5.6).

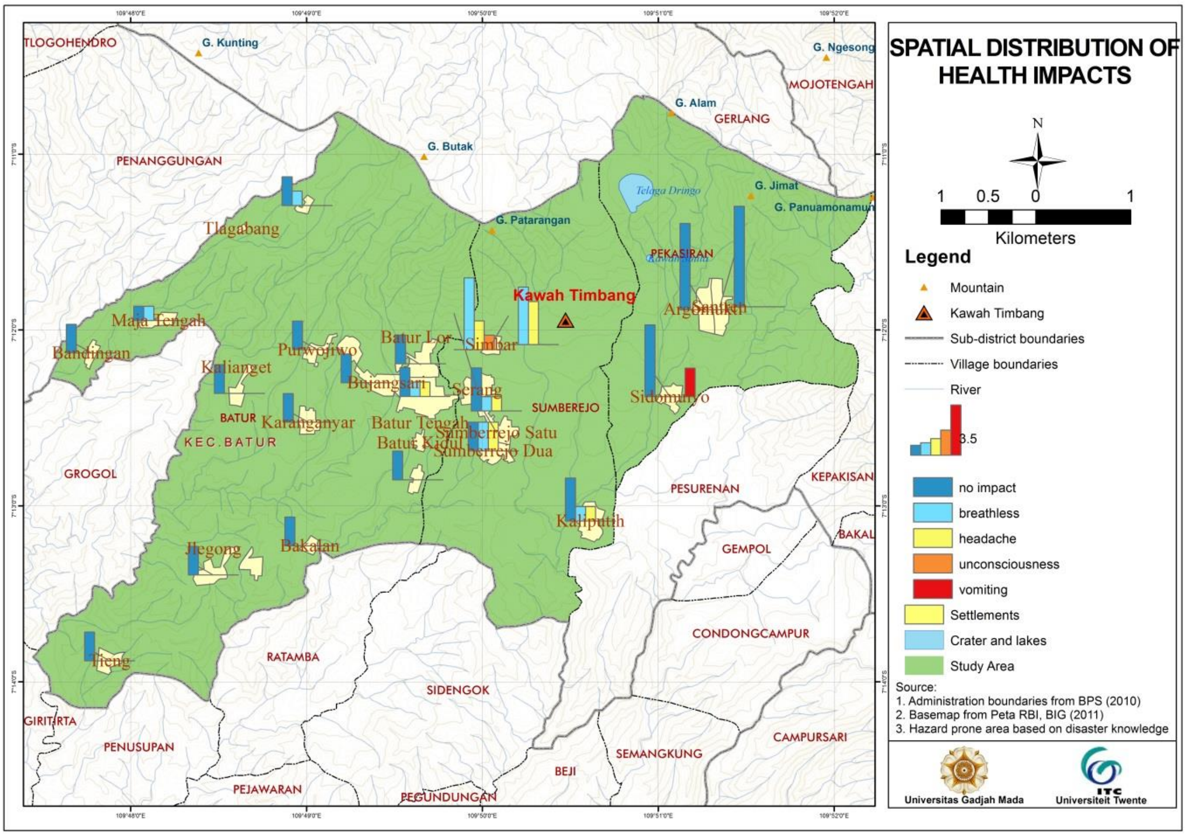


Figure 5.6 Spatial distribution of health impacts each hamlet

About 8.2% of respondents were also affected by the gas by experiencing the accelerated breathing (breathless). The respondents said that they felt breathless because of the smell of the sulphur gas. It was not clearly identified that the gas which make people breathless is carbon dioxide (CO_2). As people did not know whether they breathe the CO_2 or not, they were not sure to say if their breathless because of the CO_2. One thing that people know is the gas which emitted was not only carbon dioxide, but also other gases like H_2S and SO_2.

In special case, some of respondents have experienced vomiting and unconsciousness. Researcher successfully interviewed some of Sinila 1979 survivors in the study area. Pak Riyanto, 66 years old, is one of Sinila 1979 survivor who experienced unconsciousness because he breathed the CO_2 gas when rescuing the victims. He stated the chronology as:

> "*At that time I was evacuating my family to Batur. My family were evacuating to Bujangsari hamlet in Batur, to our relatives. Then, I managed to go back because there was a valuable document (SK) that had to be secured. On the way to go back, some friends told me that there were eruption victims on the main road. At that time, there was adzan Subuh, and then I managed to pray before continue to rescue people. The situation was very dark at that time I had placed one body to a car, after that I managed to rescue another, trying to carry the body which lie on the ground. But, when I was trying to carry the body, I breathed the carbon dioxide. When I breathed it, I realized that I breathed toxic gas, after that, I ran. Less than 10 meters from that spot, I was collapsed. I was trying to call a friend, but I could not. I fell. I was pulled by someone for about 2 meters then I continued to crawl for about 30 meters. After that I got unconsciousness. I woke up at Batur shelter then after that then came back to my family.*"

Figure 5.7 Health treatments in Kecamatan Batur, Sinila disaster 1979
(Photo credit: Harsaja)

Besides Pak Riyanto, there was also Sinila 1979 survivor who experienced bad health impacts. Pak Marjini, 75 years old, is one of Sinila 1979 survivor. He is now living in Sidomulyo, Pekasiran. When interviewing Pak Marjini, researcher got helped by friends and Pak Marjini's son to translate the Javanese language into Indonesian. Pak Marjini experienced vomiting at Sinila 1979 disaster. Pak Marjini vomited with blood. His son also stated that Pak Marjini experienced unconsciousness. Pak Marjini were evacuated to Batur and got the treatment on Kecamatan Batur.

Table 5.5 Chi-Square test for Distance and Health Impacts

	X^2	*df*	*P*	*Result*
Distance and Health Impacts	29.204	3	0.000	Related

$*p < 0.05$

Table 5.5 above presents the result of chi-square test for *distance (*the respondent's location in radius to Timbang crater*)* and *health impacts*. Health impacts data were categorized into two general categories: *no impact* and *impacted*. The chi-square test shows that the *distance* has a significant relation with the health impacts (0.000 < 0.05). Based on those findings, it is identified that the health impacts of CO_2 volcanic gas is related to *distance* (see Figure 5.6). The health impacts of volcanic gas that people have for years can be a lesson learned for a better preventive mitigation in the future.

Livelihood impacts

In terms of livelihood, the impacts of volcanic gas disaster were mostly experienced by farmers. Farmers are the most vulnerable group. Disaster can cause economic implications on people lives. Figure 5.8 shows the spatial distribution of livelihood impacts each hamlet. From the map it can be seen that Batur village mostly has *no impact*, while Sumberrejo and Pekasiran have livelihood impacts, such as *impacted livestock and crop fields*, and *temporary lose jobs*.

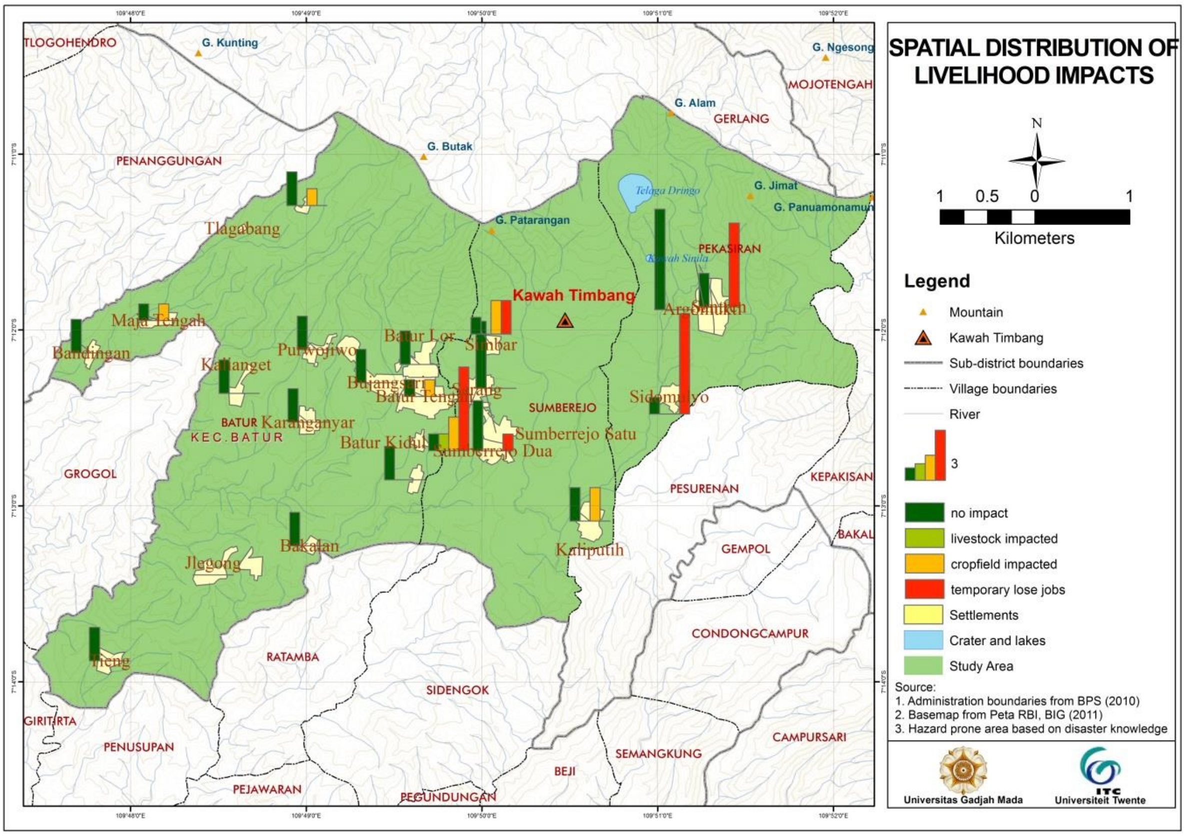


Figure 5.8 Spatial distribution of livelihood impacts each hamlet

Figure 5.9 Mr Tunut from PGA, showing the plants which perished by gas
(Source: Surip, PGA Dieng)

In 2013, almost 20 ha of potato fields were damaged because of the CO_2 emission in Timbang crater (Kompas, 2013). Pak Suharto, one of respondent in Simbar, stated:

"*As a farmer, we were having enough losses because of the gas disaster. The vegetables perished. Even though some of vegetables fields were not really affected by gas, the agricultural laborers still were afraid of gas. Thus, many vegetable fields were abandoned for about three months. We did not get money at the disaster periods. That was a crisis for both land owners and laborers.*"

The volcanic gas disaster was really affecting people lives. Because Dieng is a rural area, the main activities in the area are agriculture activities. When disaster occurred, some farmers could not harvest their agricultural lands. The laborers could not get the daily salary. And people whose jobs are farming distributor (driver) could not do their job because there were no vegetables to distribute. Some people lose their jobs temporarily. In 2013, it was a crisis for about three months.

Figure 5.10 Volcanic gases on agricultural lands
(Source: Surip, PGA Dieng)

Table 5.6 below shows the result of chi-square test for *distance (*the respondent's location in radius to Timbang crater*)* and *livelihood impacts*. The livelihood impacts were categorized into two categories: *no impact* and *impacted*. The chi-square test shows that the *distance* has a significant relation with the livelihood impacts (0.012 < 0.05).

Table 5.6 Chi-Square test for Distance and Livelihood Impacts

	X^2	*df*	*P*	*Result*
Distance and Livelihood Impacts	10.958	3	0.012	Related

$*p < 0.05$

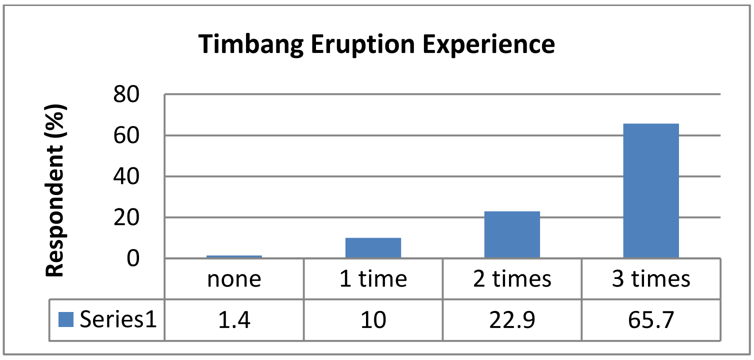
5.3 Timbang Disaster Experience and Risk Perception

This sub-chapter discusses about Timbang eruption experience, evacuation experience, and risk perception.

5.3.1 Timbang Eruption Experience

Based on fieldwork results, the majority of respondents had experienced the Timbang eruption two and three times (since Sinila disaster in 1979). About

65.7% respondents stated that they had experienced disaster for 3 times. While 22.9% of respondents stated that they had experienced disaster for 2 times since they were born.



Graph 5.7 Dieng eruption experience

The disaster experience can be a lesson learned and lead community to a better disaster management and improve awareness. The more they have experiences; the more they aware and stay alert. The spatial distribution of disaster experiences is shown in Figure 5.11:

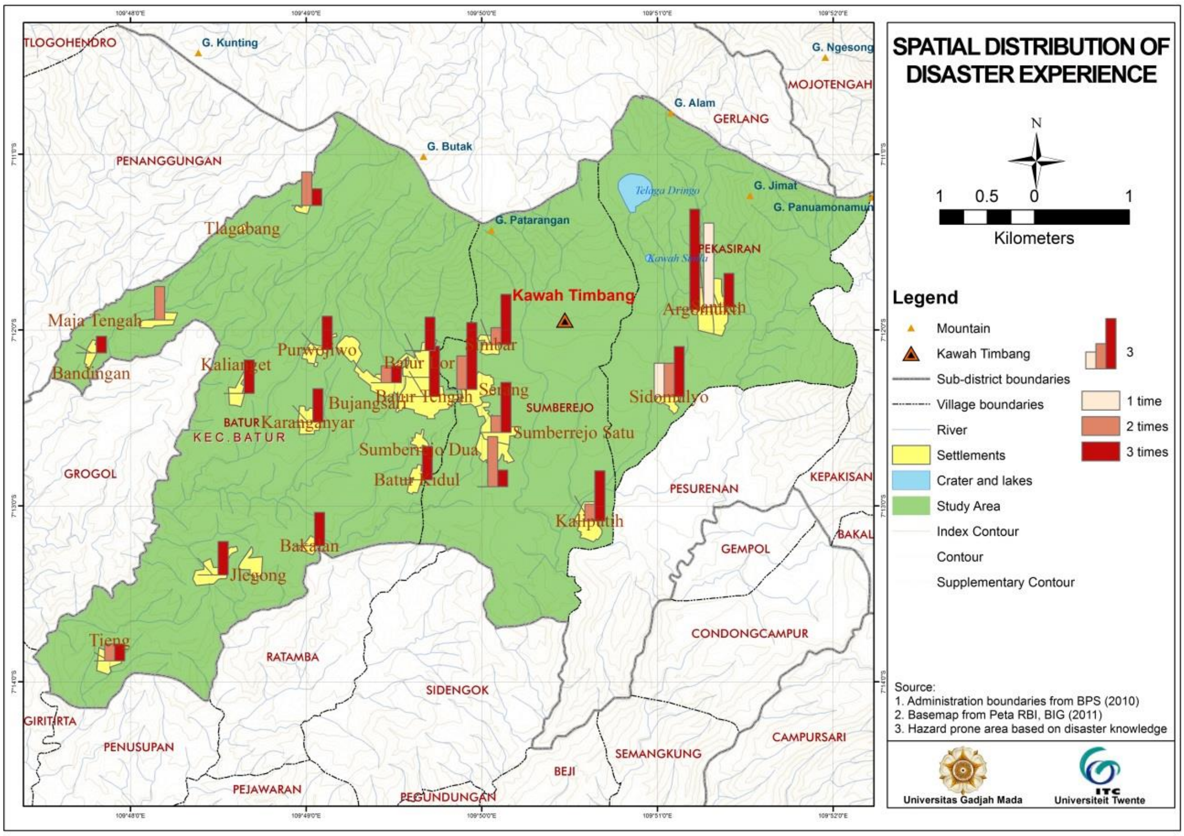
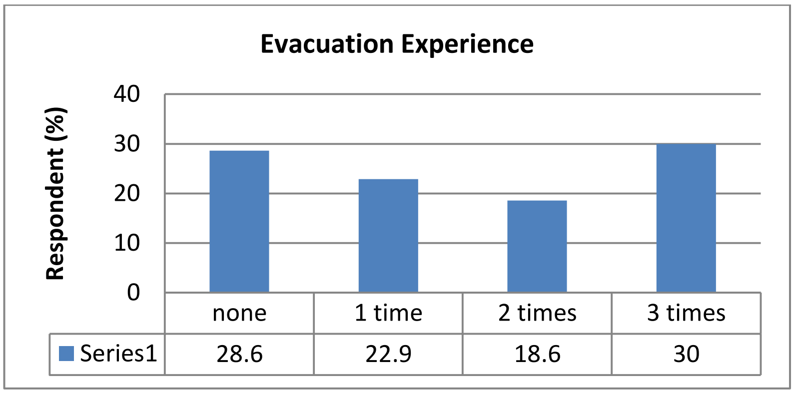
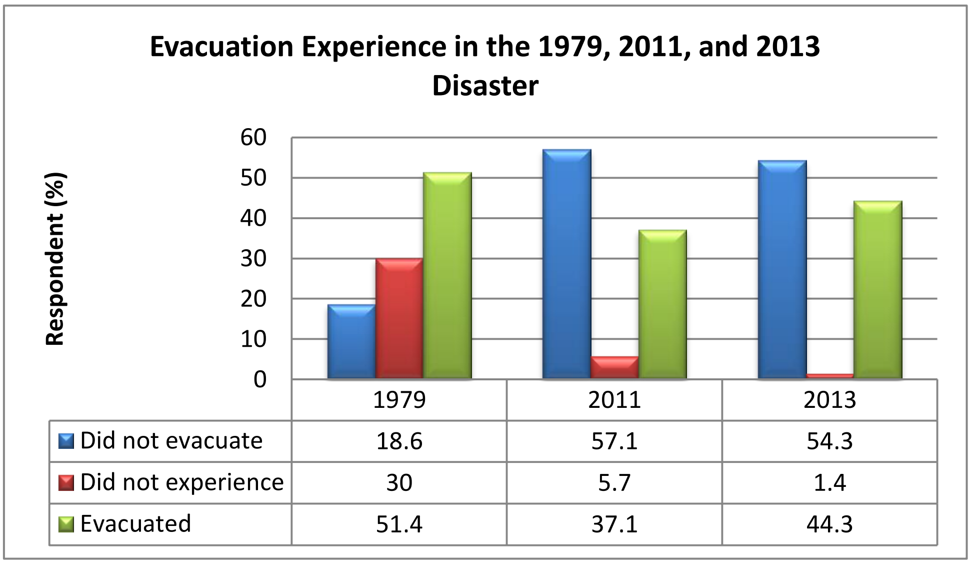


Figure 5.11 Spatial distribution of disaster experience based on hamlet unit



Graph 5.8 Evacuation Experience

Even though most of respondents have experience the disasters, not all of them are experienced in evacuation. Based on fieldwork results, there are people who have no experience in evacuation. About 28, 6% of respondents have no experience in evacuation. While others have experienced to be evacuated 1-3 times (see Graph 5.8).



Graph 5.9 Evacuation experience in the 1979, 2011, and 2013 Timbang disaster

In Sinila disaster 1979, 51.4% of respondents evacuated (see Graph 5.9). In Timbang disaster 2011, respondents mostly stayed at home, they did not evacuate as they know that the volcanic gases just flew near Timbang. About 57.1% of respondents did not evacuate at that time. People tend to feel safe staying at home than going to the evacuation shelter.

In 2013, people also tend to stay at home. The respondents who did evacuate were the respondents who live in radius < 1 km and 1-2 km from Timbang crater. Spatially, the evacuation experiences of respondents in each time can be shown in the flow maps (Figure 5.12; Figure 5.13; Figure 5.14).

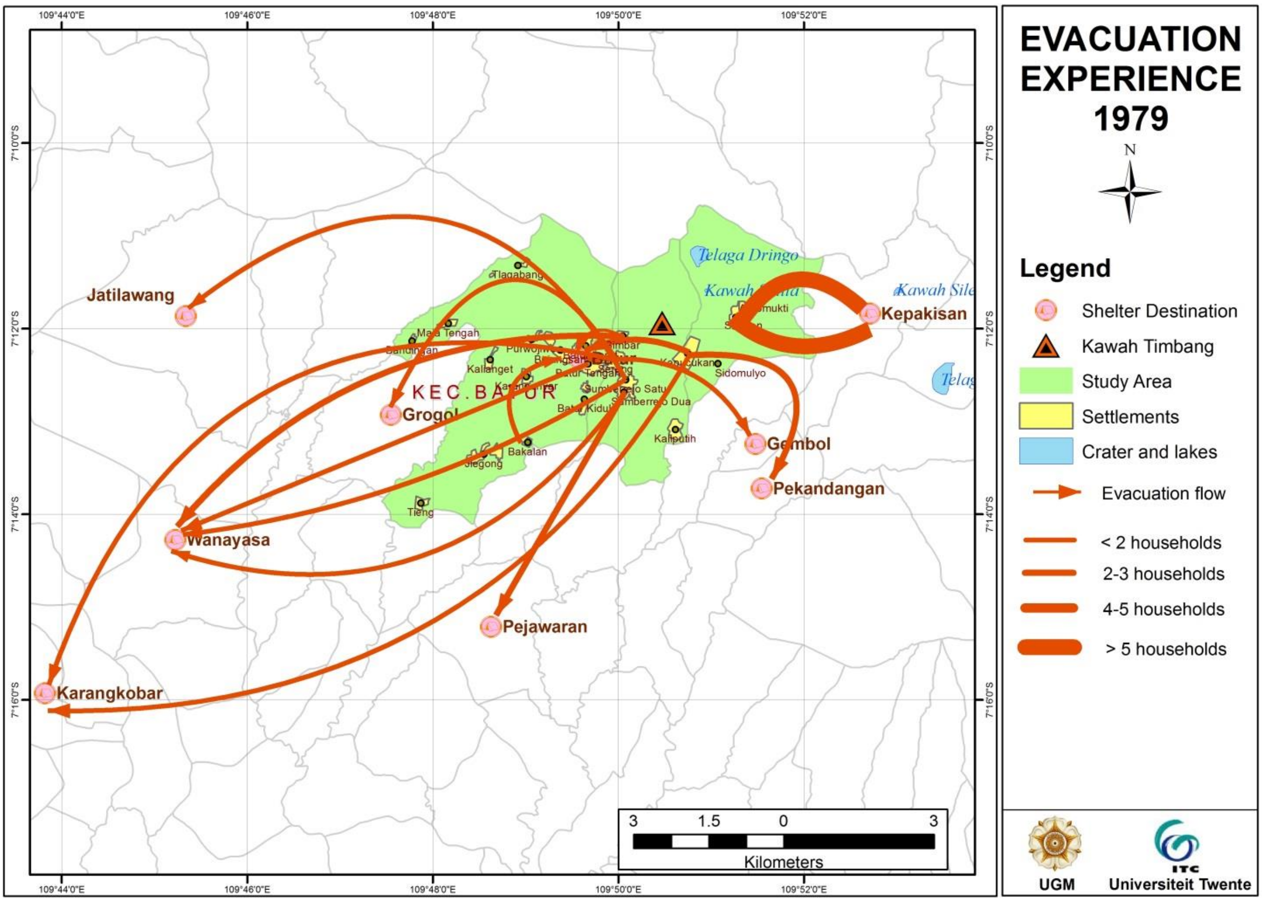


Figure 5.12 Evacuation experience of Sinila 1979 disaster flow map
(Source: Data processing)

Figure 5.12 above shows the evacuation flow of respondents on Sinila 1979 disaster. From the map it can be seen that there were many evacuation destinations. Respondents who lived in Sumberrejo and Batur village mostly evacuated to Batur evacuation shelter (in Batur government office). But some of them tend to evacuated themselves to the western part of study area avoiding the Timbang and Kepucukan areas. The western destinations were Jatilawang, Wanayasa, Karangkobar, Grogol, and Pejawaran. The respondents which lived in radius >2 km from Timbang crater stayed at their houses; it can be seen on the map that some hamlets do not have the evacuation flow direction (Tlagabang, Bandingan, Maja Tengah, Jlegong, Tieng, Kalianget, Batur Kidul, and Kaliputih). The other evacuation destinations are on the eastern part of the study area. Respondents who lived in Pekasiran village (Argomukti, Santren, and former Kepucukan) evacuated themselves to Kepakisan, Gembol, and Pekandangan.

It is important to note that at that time, besides Batur shelter, there were no official evacuation shelters which prepared by the government. Because the disaster was very huge and threatening, respondents felt that they need to go to the safer areas which avoiding Timbang crater, thus they had motivation to go away from their village to evacuate themselves.

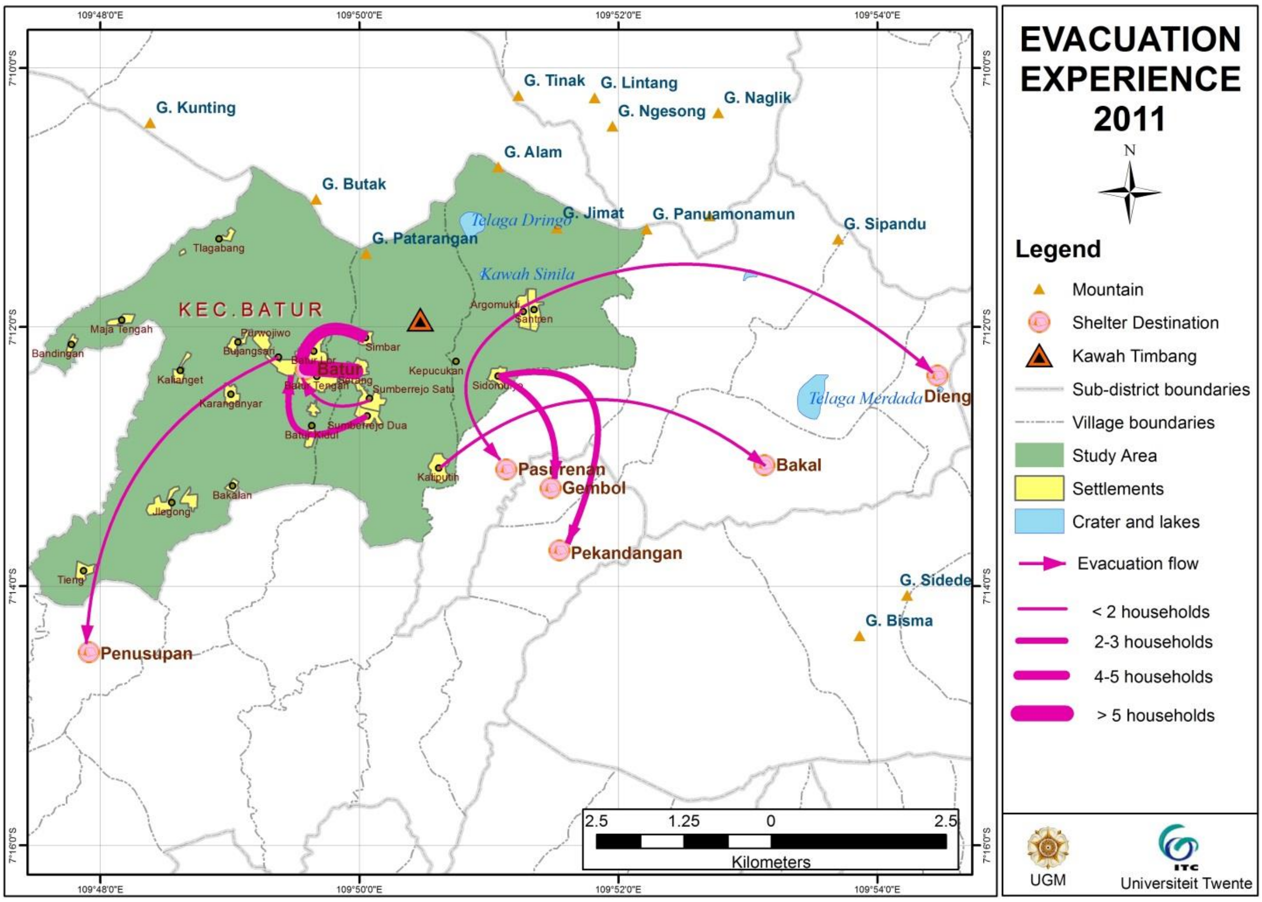


Figure 5.13 Evacuation experience of Timbang 2011 disaster flow map
(Source: Data processing)

From Figure 5.13, it can be seen the evacuation flow of respondents on Timbang 2011 disaster. From the map it can be seen that there were fewer evacuation destinations comparing to Sinila 1979 disaster. Respondents mostly stated that they have lesson learned from previous Sinila disaster. In addition, the magnitude of the disaster was different with the past Sinila 1979 disaster. In Timbang 2011 disaster, there were no casualties. Still, the earthquakes were widely felt and there was emission of CO_2 from Timbang crater which produced a ground-hugging gas layer reaching 1 m above ground level in radius 1 km of the crater.

The respondents who lived in Batur village mostly stayed at home instead of go to the evacuation shelters; one respondent in Bujangsari hamlet evacuated to Penusupan, the southern area of study area (see Figure 5.13). Respondents who lived in Sumberrejo village (except Kaliputih hamlet) mostly evacuated to Batur evacuation shelter. The respondents from Kaliputih hamlet and Pekasiran village (Argomukti, Santren, and Sidomulyo) tend to search safer area to the eastern part of study area. They evacuated to Dieng, Bakal, Pasurenan, Gembol, and Pekandangan.

Figure 5.14 shows evacuation flow of respondents on Timbang 2013 disaster. From the map it can be seen that there were more evacuation destinations comparing to Timbang 2011 disaster. The magnitude of Timbang 2013 disaster was as high as Sinila 1979, but there were no casualties in this time. Still, just like Timbang 2011 disaster, the earthquakes were widely felt and there was emission of CO_2 from Timbang crater which produced a ground-hugging gas layer reaching 1 m above ground level in radius 1 km of the crater. But, at this time, the magnitude of the earthquakes were higher, thus few buildings in Pekasiran and Kepakisan village were damaged.

Like evacuation patterns on Sinila 1979 and Timbang 2011 disasters, the evacuation patterns consist of two patterns: the western pattern and the eastern pattern. The western evacuation destinations were Batur shelter, Ratamba and Pejawaran village. Respondents in Sumberrejo were mostly evacuated to Batur shelter. Meanwhile, the eastern evacuation destinations were Pasurenan, Gembol, Bakal, Pekandangan, and Dieng.

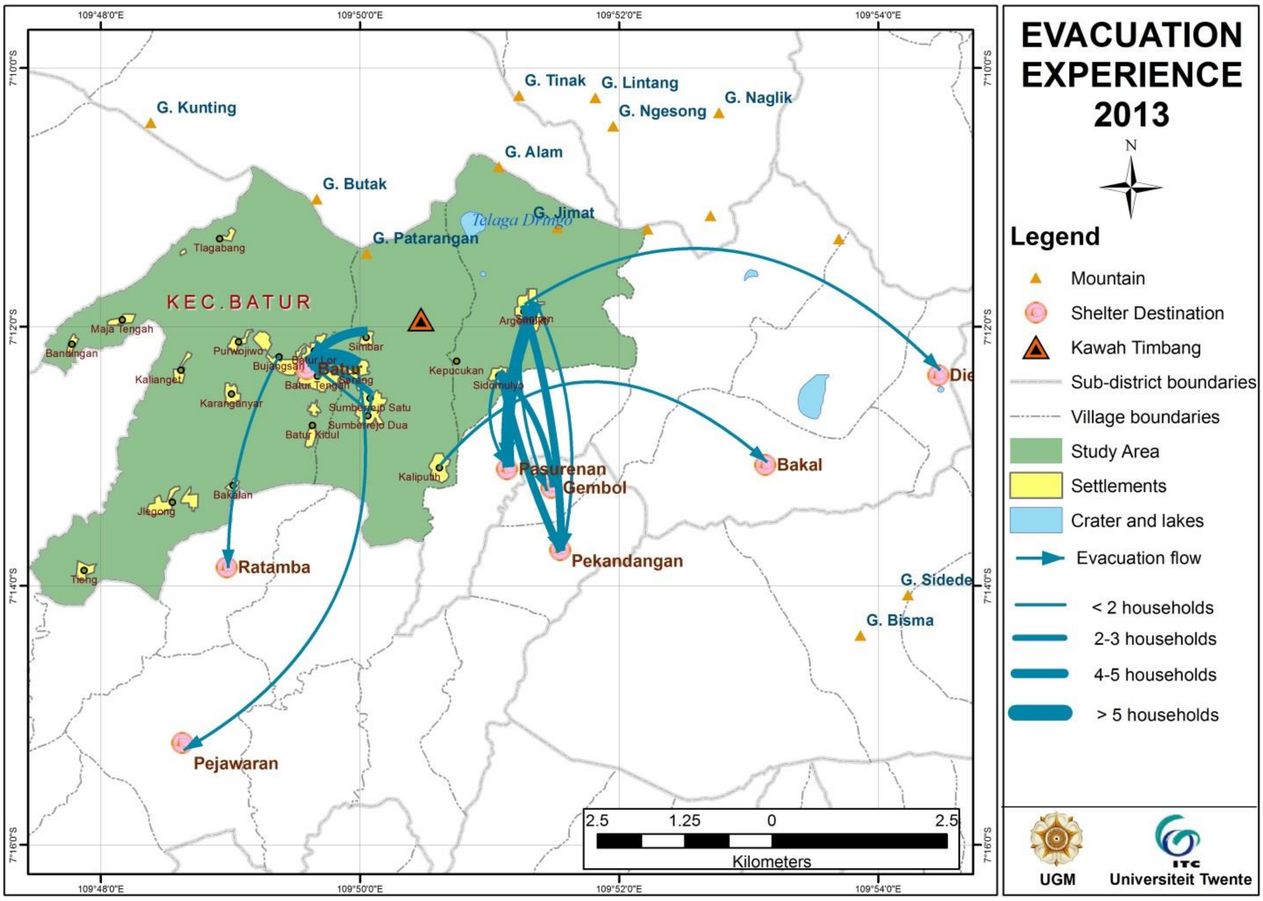


Figure 5.14 Evacuation experience of Timbang 2013 disaster flow map
(Source: Data processing)

From the discussions above it can be concluded that people have disaster experiences which influence their future behaviors especially towards disaster. From 1979 to 2013 evacuation patterns, it can be seen that people have changed their evacuation destination. The evacuation pattern has changed as well as people have changed their risk perception based on their experience and knowledge. The disaster experiences are also related to risk perception, which is also important to be analyzed in order to understand why people do certain behaviors and make decision due to disaster risk reduction.

5.3.2 Risk Perception

The discussion of disaster experiences in the previous sub-chapter shows that disaster experiences are related to risk perception. In this sub-chapter, risk perception was identified using various measures which consist of: perception of *hazard likelihood*, perception of *threaten life*, perception of *affect life quality*, perception of *financial loss*, and the perception of *dread*.

Hazard Likelihood

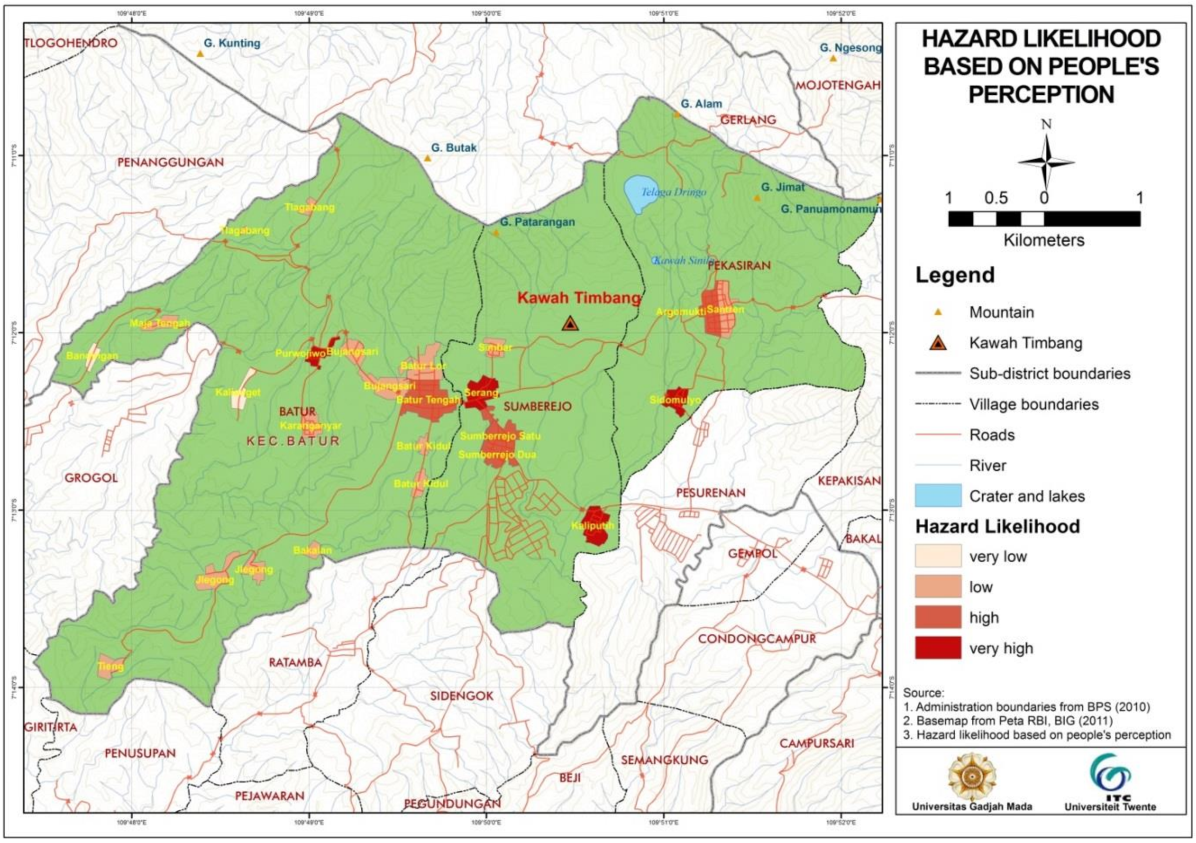


Figure 5.15 Hazard likelihood in each hamlet based on people's perception

In the risk perception about hazard likelihood, researcher asked respondents about the likelihood of hazard to occur in their locations (See Appendix 1). The result shows that respondents which live in radius 2 km tend to bring *high* and *very high* score of hazard likelihood (see Figure 5.15). The hamlets which have *very high* hazard likelihood are Serang, Kaliputih, and Sidomulyo. Simbar, the nearest hamlet (from Timbang) has *low* score of hazard likelihood; it is because the respondents in Simbar stated that Simbar elevation is higher than Timbang, which makes Simbar is safe from volcanic gases threat.

Threaten Life

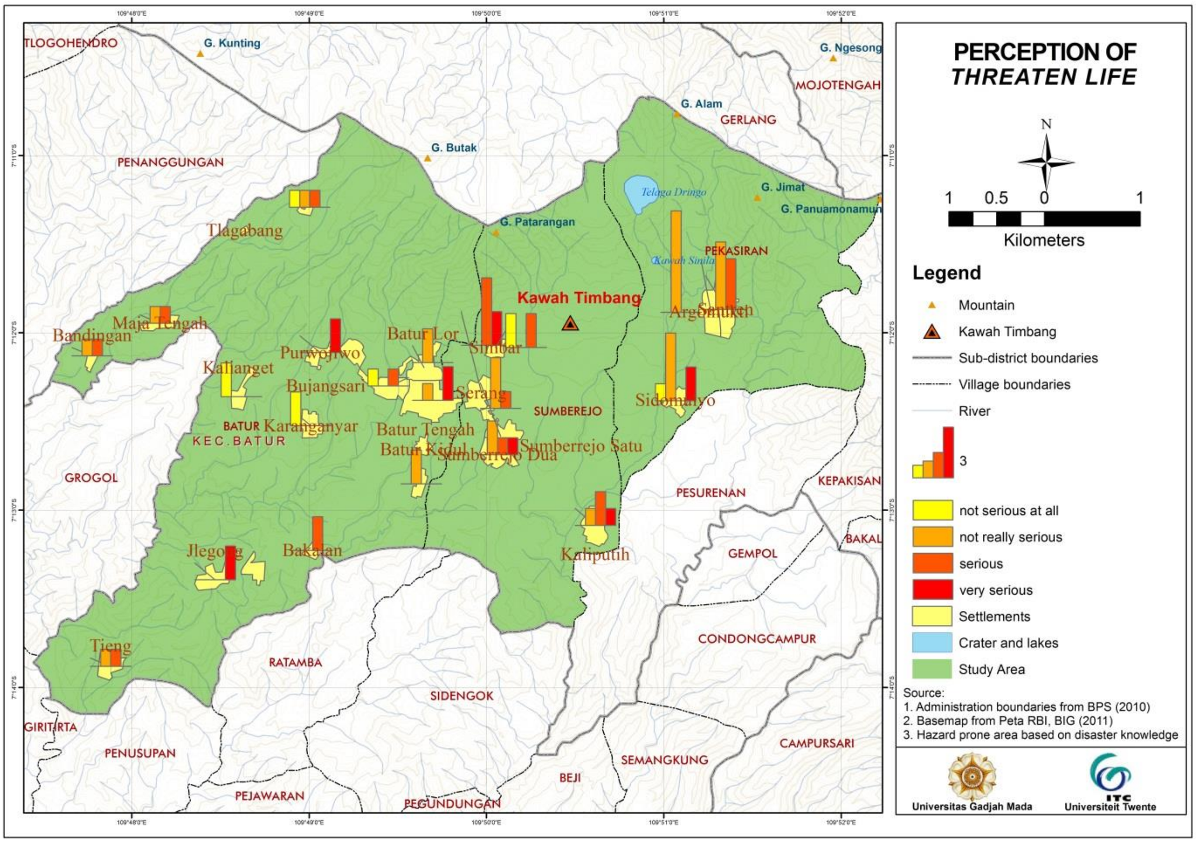


Figure 5.16 Perception of *Threaten Life* in each hamlet

In the risk perception about *threaten life*, researcher asked respondents "*to what extent does the gas threaten your life?"*. The spatial distribution of perception of *threaten life* is shown on Figure 5.16. The result shows that the respondents have various answers to this question. Even though almost of the respondents know that the toxic volcanic gas disaster is deadly and dangerous, most of respondent felt that the disaster was less life threatening (41% respondents answered *not really serious*, 13% respondents answered *not serious at all*). Meanwhile, there were also respondents who felt that the disaster was really life-threatening. The total respondents who answered *serious* are about 29% while the respondents who answered *very serious* are about 17%.

Affect Quality of Life

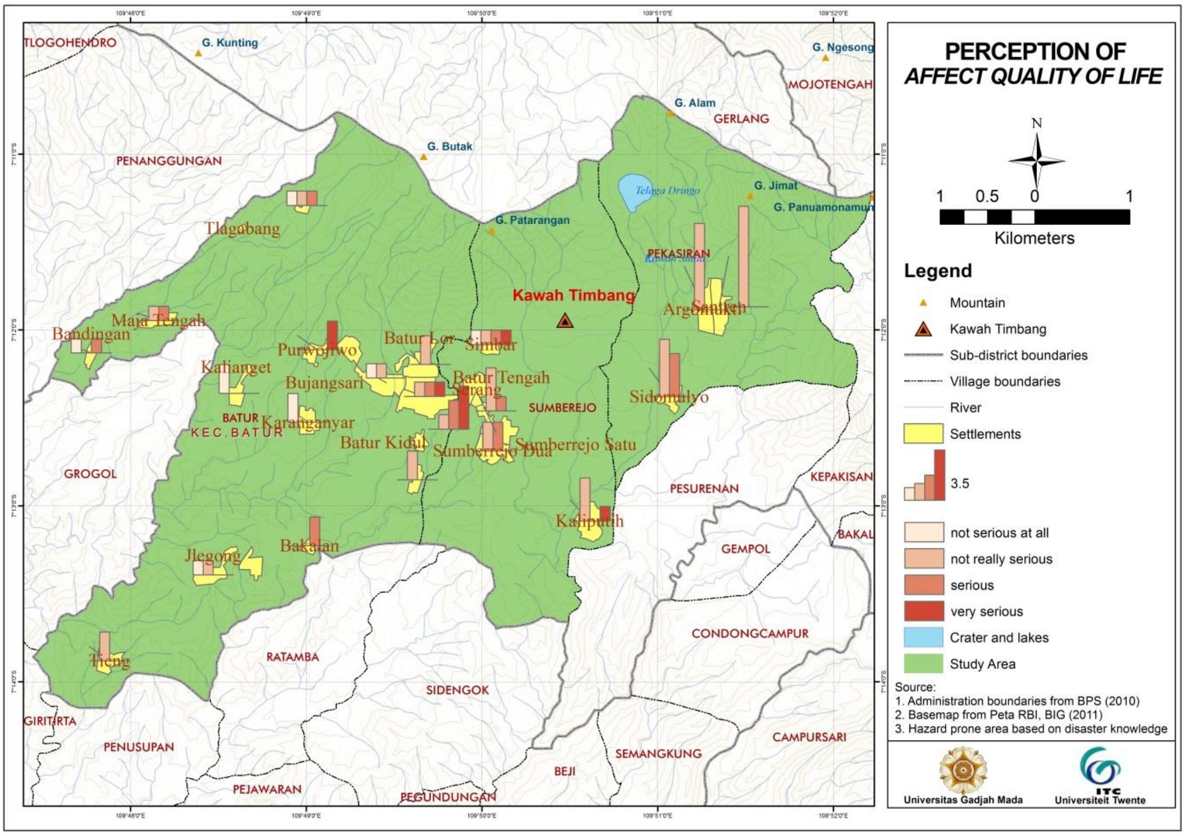


Figure 5.17 Perception of *Affect Quality of Life* in each hamlet

In the risk perception about *affect quality of life* researcher asked respondents "*to what extent does the gas affect the quality of your life?*" The spatial distribution of perception of *affect quality of life* is shown on Figure 5.17. The result shows that the respondents have various answers to this question. Most of the respondents felt that volcanic gas disaster does not really affect their quality of life. About 53% of respondents answered *not really serious* and 11% of respondents answered *not serious at all* to this question. Meanwhile, 23% of respondents answered *serious* and 13% who answered *very serious*.

Financial Loss

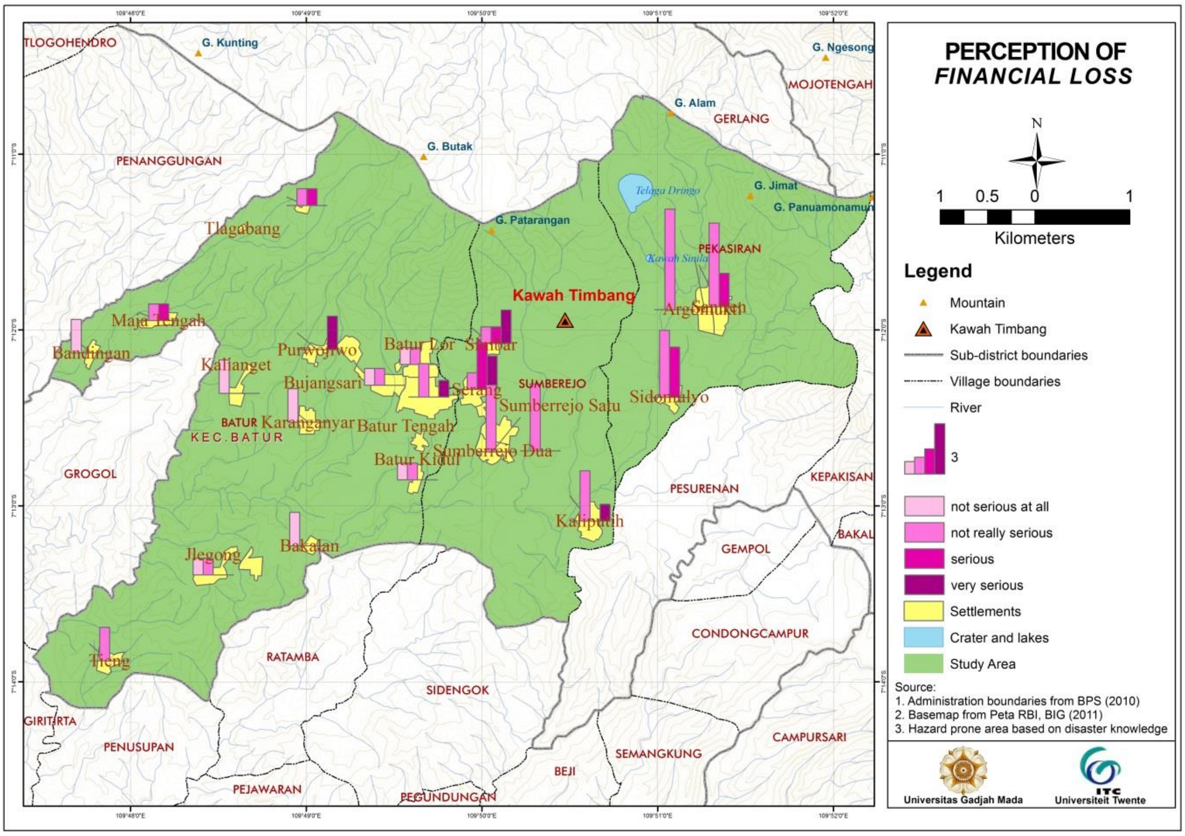
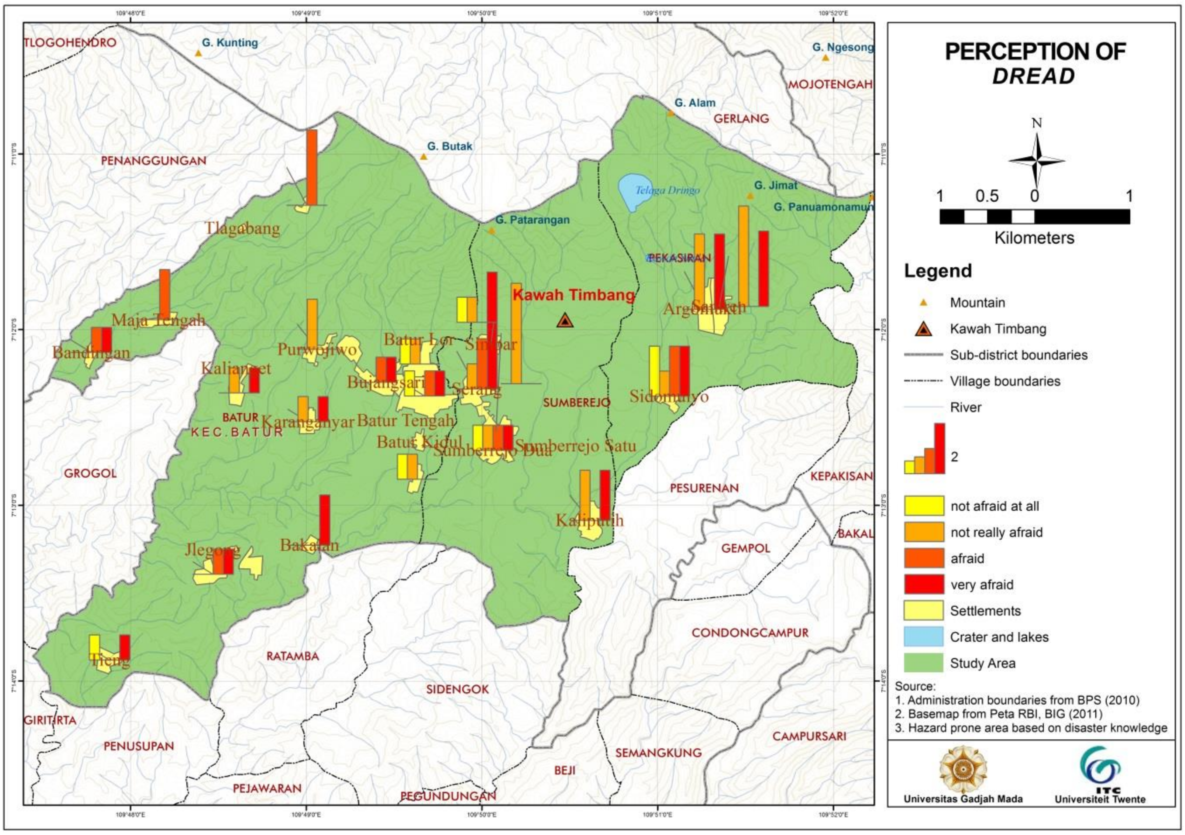


Figure 5.18 Perception of *Financial Loss* in each hamlet

In the risk perception about *financial loss*, researcher asked respondents "*to what extent does the gas bring you financial loss?"* Since the livelihood of the people are mostly from agriculture, it is assumed that when disaster occur, there will be many agricultural lands which affected by the disaster. The affected agriculture land will also indirectly bring financial loss to the people. But, the result shows that the respondents mostly stated that the disaster does not bring *serious* financial loss. The spatial distribution of perception of *financial loss* is shown on Figure 5.18.

About 54% of respondents answered *not really serious* and 17% of respondents answered *not serious at all* to the question. Meanwhile, there were few respondents who felt that the disaster seriously bring financial loss. About 16% of respondents answered *serious* and 13% of respondents answered *very* *serious* to the question. They are mostly the people who live near Timbang (Simbar and Serang hamlet), further analysis about the risk perception and distance will be discussed in the next sub-chapter.

Dread



5.19 Perception of *Dread* in each hamlet

In the risk perception about *dread*, researcher assessed the sense of dread by asking respondents "*in general, how afraid are you of the toxic gas?"* The spatial distribution of perception of *financial loss* is shown on Figure 5.19.

The result shows that the respondents have various answers to this question. Most of the respondents felt that they are afraid of volcanic gas disaster. About 35.7% of respondents answered *very afraid*, and 20% of respondents answered *afraid*. Meanwhile, 11,4% of respondents stated that they do *not afraid at all* with volcanic gases, and 32,9% of respondents answered *not really afraid* with volcanic gases.

5.4 Coping Capacity

This sub-chapter discusses about the strategies and practices that people have done in order to cope with CO_2 volcanic gas disaster including the disaster management. Each coping capacity is categorized into two time dimension: during normal times and during the disaster.

5.4.1 Community's coping capacity

Based on fieldwork results, there are several strategies and practices that Dieng people do in order to cope with CO_2 volcanic gas disaster. Since they have been living in Dieng for years, Dieng people have become familiar with CO_2 volcanic gas. The coping strategies that they have are basically based on disaster experiences which transferred from generation to generation within communities. During the fieldwork interviews, the respondents were asked using open questions related to their coping practices in two time dimensions (during normal times and during disasters). In order to better understand and analyze the coping practices, the strategies and practices that people have are categorized based on the basis of their objectives. According to Wamsler & Brink (2014), the coping objectives were categorized into:

- hazard reduction and avoidance: to limit or avoid current and future hazards;
- vulnerability reduction: to reduce current and future vulnerability to hazards;
- preparedness for response: to provide functional and flexible mechanisms and structures for disaster response; and
- preparedness for recovery: to provide functional and flexible mechanisms and structures for disaster recovery

The coping practices gathered from fieldwork, during normal times and during disasters are shown in Table 5.5 and Table 5.6:

Table 5.5 Households' coping practices during normal times

Objectives	Coping practices
Hazard reduction and avoidance	1. Avoid hazard-prone locations for residential expansions
	2. Avoid go to the Kaliputih and Kalisat river in the dawn and evening
Disaster preparedness	1. Maintain contact with Volcanology Office and BPBD (hamlet head)
	2. Prepare the emergency bag (clothes, basic food items)
	3. Mitigation and evacuation training for the youth and administrative officers
	4. Disaster simulation in Batur Sub-district

Table 5.5 above provides a summary of households' coping practices during normal times. During the normal times, there are only few things that can be done to cope with volcanic gas disaster. The Dieng people do not have particular adaptive coping capacity due to the volcanic gas disaster in normal times. The Dieng people deploy *hazard reduction and avoidance* with avoiding hazard-prone locations: 1. Avoid hazard-prone locations for residential expansions; 2. Avoid go to the Kaliputih and Kalisat River in the dawn and evening. Based on their local knowledge, people do not expand their homes into known hazard-prone locations, as known that human settlement is one of factors that vulnerability originates in (Bankoff et al., 2004). Secondly, Dieng people have known where the hazardous areas based on their disaster knowledge and experiences. The Dieng people, especially farmers, avoid go to Kaliputih and Kalisat River in the dawn and evening as they know the toxic gases always flow there when there is no sunlight.

For *disaster preparedness*, almost all hamlet heads maintain contact with Volcanology Office (PGA) and BPBD Banjarnegara. The source of information about the Timbang status is the Volcanology Office (PGA) and BPBD Banjarnegara. The Head of Dieng Volcanology Office, Mr. Tunut has always communicated with hamlet heads and village officials using mobile phones, both during normal times and during the disaster. Other practices which have been deployed by Dieng people are: preparing the emergency bag, mitigation and evacuation training for the youth and village officials, and disaster simulation. Only some people prepare the emergency bag, especially the people who live in Simbar and Serang. It is because most of Simbar and Serang dwellers tend to stay back at their houses.

While during the disaster, there are several coping practices identified based on interview and field observations. The coping practices are shown in the Table 5.6:

Table 5.6 Households' coping practices during disaster

Objectives	Coping practices
Hazard reduction and avoidance	1. Avoid go to the Kaliputih and Kalisat river in the dawn and evening
	2. Avoid go to Gua Jimat when Timbang crater is active
	3. Maintain contact with Volcanology Office and BPBD (hamlet head)
	4. Construct barriers using bamboo and plastic to reduce agricultural exposure
	5.Being included in resettlement projects: transmigration to Baturraja and *bedol desa* (Sinila 1979 disaster)
Vulnerability reduction	1. Distribute the masks to reduce breathe the volcanic gases
	2. Prepare wet towel to reduce breathe the volcanic gases
	3. Provide shelter for relatives (those who are far from Timbang)
Disaster responses	1. Disseminate volcanic gases information
	2. Evacuate the children, women, and elder people
	3. Elder people, women and children stay at evacuation shelters
	4. Men stay at home to guard their houses and protect their belongings (avoid thefts)
Disaster recovery	1. Borrowing money from relatives or neighbors
	2. Looking for alternative jobs
	3. Psychosocial training for children to recover trauma
	4. Adjusting agricultural planting time

Besides avoiding Kaliputih and Kalisat areas, some people in Pekasiran village avoid go to Gua Jimat when Timbang crater is active. Gua Jimat is also one of toxic gas hazardous area in the study area. Other *hazard reduction and avoidance* measure is, in some occasions, people especially farmers, construct barriers using bamboo and plastic to protect crops from toxic gases. The land owners who own agricultural land in radius 1 km (or also 1-2 km) from Timbang mostly coped with the disaster by constructing barriers. This also can be categorized as *vulnerability reduction*, where the agricultural losses can be reduced by this coping practice. The agricultural barriers can be seen in Figure 5.3 below:

Figure 5.3 Volcanic gases barrier using bamboo and plastics (1 meter height).
(Source: Surip, PGA Dieng)

One of the most interesting findings in *hazard reduction and avoidance* is the resettlement project (transmigration and *bedol desa)* at Soeharto era (at Sinila 1979 disaster). Based on in-depth interview with informants, it is known that the most affected village, Kepucukan, was banished. The access to Kepucukan was cut and Kepucukan village was changed into plantation. The Kepucukan dwellers were offered by government to move permanently to Baturraja in Ogan Komering Ulu, South Sumatera for transmigration projects. About 200 households participated in that transmigration project. Meanwhile, there were some of Kepucukan dwellers who did not want to go to Baturraja, thus they established a new settlement in the eastern Kepucukan, which is now called Sidomulyo hamlet. At that time, there were only 17 households which live in Sidomulyo.

For *vulnerability reduction*, the government distributes the masks to the community. Meanwhile, community has their own common disaster knowledge that the better preventive masks is using wet towel. If toxic gas emission occurs, people prepare towel and water (to make it wet) then use it as a mask. This method had not been known at Sinila 1979 disaster. Some of respondents stated that they know this knowledge from Palang Merah Indonesia (PMI). Scientifically, wet towel/cloth can absorb some of the smoke particles and filter noxious substances, in this case carbon dioxide (CO_2), thereby reducing CO_2 inhalation. The wet towel/cloth will not eliminate the smoke inhalation, but it only reduces the smoke inhalation for a short time. The more people have time to escape, the greater the likelihood of survival.

For *disaster responses*, the hamlet head disseminate the status update of volcanic gases information to the community. From village level to community level, the information about Timbang status then will be distributed to the community through the conventional ways: door to door. Instead of using speaker in mosque in the neighborhood, the *door to door* method was used to avoid panic. Other measures for *disaster responses* are evacuating the most vulnerable groups (children, women, and elder people) and guarding the houses to avoid thefts.

For disaster recovery, there are some people who need to borrow money from relatives or neighbors when disaster occurs. The agriculture laborers were the vulnerable ones because they only have daily salary for their everyday needs. Thus, when there are no agriculture lands to work, they will have no money.

5.4.2 Community Disaster Management

Disaster management in Dieng is a part of coping capacity which government and community conduct. Structural and non-structural mitigation have been conducted in response to Timbang eruption in Dieng. There are many government institutions and non-governmental organizations (NGO) which involved in Dieng disaster management. The institutions and the role of each institution in Dieng disaster management are shown in the table below:

Table 5.7 Institutions and its role in Dieng disaster management

<table>
<tr><th>Institutions</th><th>Role in volcanic gases disaster management</th><td rowspan="8">Roles of institution:
1. Risk assessment
2. Prevention
3. Preparedness
4. Awareness raising
5. Mitigation
6. Warning/evacuation
7. Saving victims
8. Damage assessment
9. Reconstruction</td></tr>
<tr><td>PGA</td><td>1, 6</td></tr>
<tr><td>BPBD</td><td>4, 5, 6, 7, 8</td></tr>
<tr><td>Batur Sub-District government</td><td>2, 3, 6</td></tr>
<tr><td>TNI</td><td>6, 7, 9</td></tr>
<tr><td>PMI</td><td>3, 5, 7</td></tr>
<tr><td>Bagana NU</td><td>2, 3, 6, 7, 9</td></tr>
<tr><td>KOKAM Muhammadiyah</td><td>2, 3, 5, 6</td></tr>
</table>

In the study area, there is a community organization which deals with disaster risk management. The community organization is KOKAM Muhammadiyah which is located in Sumberrejo Village. KOKAM Muhammadiyah is a sub-division of Muhammadiyah Islamic organization which established in almost every disaster-prone area administratively. KOKAM Sumber (Sumberrejo) has 15 members which consist of youth and young adults living in Sumberrejo Village. According to Pak Zaenal, the head of KOKAM Sumber, there is about 100 members of total in Banjarnegara Regency; thus the KOKAM Sumber has 15% of total members in Banjarnegara Regency.

The roles of KOKAM Sumberrejo related to volcanic gases disaster management are:

- Psychosocial training for children to recover trauma
- Economic recovery by helping and support people who temporarily lose jobs to find alternative jobs
- Disaster mitigation and disseminate disaster information, cooperate with PGA Dieng

Beside KOKAM Sumber, there is also one community organization which deals with disaster management in Dieng. The community organization is BAGANA Nahdlhatul Ulama (NU) which is based in Bakal Village, the eastern of study area. BAGANA NU is also a sub-division of the NU Islamic organization. BAGANA NU is a well-established disaster organization which now has member of 246 people. BAGANA NU has always participated in disaster management training which held by BPBD Banjarnegara (two times in 2 years).

The roles of BAGANA NU Bakal related to volcanic gases disaster management are:

- Help PGA in gas measurements by send some members to help PGA officials
- Evacuate people when disaster occurs
- Coordinate with BPBD Banjarnegara and PVMBG

5.5 Discussion of Human Vulnerability, Risk Perception, and Coping Capacity

This sub-chapter discuss about the human vulnerability, risk perception, and coping capacity. Firstly, the discussion is about the relationship between human vulnerability and risk perception. Secondly, the discussion is about the comparison of coping capacity in Dieng and in Lake Nyos Cameroon. Since the coping capacity was not assessed quantitatively, researcher compares coping capacity generally between the research result and the previous research which is related with CO_2 volcanic gases disaster.

5.5.1 Human Vulnerability and Risk Perception

The relationship between vulnerability attribute (distance, include disaster impacts) and risk perception were analyzed using ordinal regression analysis. Researcher used SPSS software to make ordinal regression analysis. Before analyze the ordinal regression, the data were examined by looking the distribution of data in frequency. After that, researcher fit the regression model by looking the Chi-square significant value of the data in *Model Fitting Information* in SPSS. If the Chi-Square significant value is below 0,05 (using 95% confidence level), the model fit with the data. If the model fit, the ordinal regression analysis can be done. The result of ordinal regression is analyzed by looking the *estimated values* and the *significant level* of the independent variable (predictor).

In this research, the independent variables are *distance*, *health impacts*, and *livelihood impacts*. The dependent variables are the risk perception items. The result will show whether the independent variables influence the dependent variable or not. It also explains whether the *distance*, *health impacts*, and *livelihood impacts* can be good predictor variables for risk perception or not.

The significant values show the significant influence of *independent* variables. If the result of significant values < 0.05, it means that the *independent* variable has a significant influence to the *dependent* variable. The results of significant values are shown in the Table 5.8 and Table 5.9 below:

Table 5.8 Regression analysis of Risk Perception and Distance

Vulnerability Attributes	**Risk Perception**				
	Hazard Likelihood	***Threaten Life***	***Affect Life Quality***	***Financial Loss***	***Dread***
Distance	0.009	0.899	0.876	0.001	0.419

*p < 0.05

From the Table 5.8 above, it can be seen that the perception of *hazard likelihood* is influenced by *distance* (0.009 < 0.05). It is clear that respondents' perceptions of hazard likelihood were influenced by the location in which they have lived. If their location is near Timbang crater, they will possibly say that the hazard likelihood in their location is high, and vice versa. The risk perception of *financial loss* is also influenced by *distance* with the score 0.001 (0.001 < 0.05). It is also clear that people who has *serious* financial loss is the people who lived near Timbang (Serang and Simbar hamlet).While the risk perception of *threaten life*, *affect quality of life*, and *sense of dread* are not influenced by *distance*. The *sense of dread* is not relatively influenced by distance because most of the respondents are mostly afraid of the disaster (anywhere their locations). While the regression analysis of risk perception and disaster impacts is shown in the Table 5.9 below:

Table 5.9 Regression analysis of Risk Perception and Disaster Impacts

Disaster Impacts	Risk Perception				
	Hazard Likelihood	***Threaten Life***	***Affect Life Quality***	***Financial Loss***	***Dread***
Health Impact	0.006	0.01	0.004	0.005	0.247
Livelihood Impact	0.376	0.011	0.019	0.051	0.081

*p < 0.05

The Table 5.9 above shows the result of ordinal regression analysis between risk perception and disaster impacts.From the Table 5.9, the risk perception items which significantly influenced by *health impacts* are *hazard likelihood, threaten life, affect life quality,* and *financial loss*. All of the regression values are below 0.005, it can be said that the health impacts influence those four risk perception items. Thus, the health impact can be a good predictor to analyze the *hazard likelihood*, *threaten life, affect life quality*, and *financial loss*. Meanwhile, the *dread* is not significantly influenced by health impacts. Meanwhile, the perception *dread* is not influenced by the health impacts (0.247 > 0.05).

For the *livelihood impacts*, the risk perception items which significantly influenced by *livelihood impacts* are *threaten life* and *affect life quality*. Other risk perception items *like hazard likelihood, financial loss*, and *sense of dread* do not have relationship with the livelihood impacts. In conclusion, the *livelihood impacts* can be a good predictor to analyze the perception of *threaten life* and *affect life quality* only.

5.5.2 Comparison between human vulnerability and coping capacity in Dieng, Indonesia and Lake Nyos, Cameroon

In terms of human vulnerability, Dieng people have rural socio-economic characteristics and disaster impacts which influence their human vulnerability. Even though the people mostly do not have high incomes, Dieng people tend to be wealthier than the people in Lake Nyos, Cameroon. Henry Bang (2008) stated in his paper that the Lake Nyos survivors are still remain very poor with low incomes. They also have limited livelihood opportunities and less to resources.

The survivors in Lake Nyos are poor and socially vulnerable to the impacts of the past tragedy in 1986 and have not regained their livelihoods. It is different with Dieng people which have so many livelihood opportunities. The Dieng people have also changed after the most disastrous Sinila disaster in 1979. The Dieng people are now better; they are more experienced and knowledgeable towards volcanic gases disaster.

In terms of coping capacity, the Dieng people are considered to have better coping strategies comparing to Lake Nyos survivors in Cameroon. Both Dieng people and Lake Nyos have been experienced in volcanic gases disasters, but their strategies are different. Lake Nyos survivors tend to have a very low resilience and limited coping strategies. Meanwhile, Dieng people has many coping strategies which conducted by both government and the community. This can explain why Dieng people still survive living well in the hazardous area.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The main objective of this study is to determine the human vulnerability and coping capacity related to CO_2 volcanic gases hazard in Dieng Plateau. Based on previous results and discussions, there are some important concluding remarks of each discussions. The concluding remarks are:

1. Based on the analysis of geo-information about CO volcanic gases in the study area, both from secondary data and participatory GIS, there are some areas which have to be concerned. Simbar, Serang, and Kaliputih hamlets in Sumberejo village were the most vulnerable area comparing to other villages. It is also because the two hamlets are the nearest ones to Timbang crater and Kaliputih is the one which directly exposed from Timbang crater.
2. The human vulnerability were determined descriptively and empirically based on socio-economic characteristics and disaster impacts. The human vulnerability based on socio-economic characteristics varies based on each characteristic (age, education level, distance, occupation, etc). Meanwhile, the human vulnerability based on the disaster impacts (health and livelihood impacts) vary based on distance between respondents location and Timbang crater.
3. People have disaster experiences which influence their future behaviors especially towards disaster. The evacuation patterns from 1979 to 2013 disaster shows that the disaster experiences changed as well as people have changed their risk perception based on their experience and knowledge.
4. There are several strategies and practice that Dieng people do in order to cope with CO_2 volcanic gas disaster. Since they have been living in Dieng for years, Dieng people have become familiar with CO_2 volcanic gas. The coping strategies that they have are basically based on disaster experiences

which transferred from generation to generation within communities. Dieng people also have community organizations which deal with disaster risk management. The existence of KOKAM Muhammadiyah and BAGANA NU increase the capacity of Dieng due to Timbang volcanic gases disaster.

5. The relationship between human vulnerability and risk perception were analyzed using ordinal regression analysis. The results show that the *distance, health impacts,* and *livelihood impacts* can be used as a predictor which influence risk perceptions. From the results, *distance* has a significant influence to the perception of *hazard likelihood* and *financial loss.* Meanwhile, the *health impact* has a significant influence to the perception of *hazard likelihood*, *threaten life*, *affect life quality*, and *financial loss*. Last, , the *livelihood impact* has a significant influence to the perception of *threaten life* and *affect life quality*.
6. The human vulnerability and coping capacity between Dieng people and Lake Nyos survivors are generally different. Dieng people tend to be less vulnerable and have better coping strategies and disaster management comparing to Lake Nyos survivors.

6.2 Recommendations

The discussion of human vulnerability, risk perception, and coping capacity in this research can be adopted by local governments as an input to improve the disaster management planning. The human vulnerability, risk perception, and coping capacity that have been revealed in this research highlight the necessities which need to be concerned in disaster management programs implementation. Based on findings in this research, researcher suggests recommendations:

1. Local government has to conduct a valid and update information about volcanic gases hazard-prone map, since there are only limited data which are available and reliable.

2. Local government needs to be more concerned about Simbar, Serang, and Kaliputih hamlets in disaster management planning, especially the evacuation planning.
3. For further research, the human vulnerability studies needs to be developed in order to widen the discussion of human vulnerability. It is an interesting topic in disaster studies if researcher is interested to combine physical aspects and social aspects of disaster causation.

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APPENDIX 1

QUESTIONNAIRE (1)

Researcher : Dwiyanti Kusumaningrum

Institution : Universitas Gadjah Mada

Research Title : Human Vulnerability and Coping Capacity Related to Carbon Dioxide (CO_2) Volcanic Gases in Dieng Plateau Central Java

Purpose : *This survey is intended only for scientific research purposes to study human vulnerability and coping capacity related to carbon dioxide in Dieng Plateau*

Questionnaire no.	: ……………………….. Interviewer: ……………………………… Date: ……………………. Time: ……
Name of respondent	: …………………………………………….
Geographical location	: Lat ………………………………….. Long ………………………………………
Address	: …………………………………………
	Hamlet: ……………… Village: ……………………

1. Respondent Profile

(1). Age	: …………………… years old		(2). Sex:	Male ☐	Female ☐
(3). Position in Household	: ………………………..				
(4). Education background	: ………………………..				
(5). Year of stay in this location	: ………………………… years				
(6). Job (Source of income)	: Teacher	☐	Merchant	☐	
	Government officer	☐	Police	☐	
	Farmer	☐	Labor	☐	
	Other ………………………………				

2. Household Profile

(7). Family members total	: ……………………….. persons	
Male	: ……………………….. persons	
Female	: ……………………….. persons	
(8). Age	: 0-5 yo ……………. persons	21-60 yo …………….. persons
	6-20 yo …………… persons	more than 60 yo ………….persons

(9). Income per month:	☐ < Rp. 800.000	☐ Rp. 800.000 – Rp. 1.500.000
	☐ Rp. 1500.000 – Rp. 2000.000	☐ > Rp.2.000.000
(10). Home ownership	: ☐ Rent	☐ Owner
(11). Agricultural land ownership	: ☐ none	☐ < 1 ha
	☐ 1-2 ha	☐ > 2 ha
(12). Livestock ownership	: ☐ none	☐ poultry
	☐ goat & cow	☐ others………….
(13). Vehicle ownership	: ☐ none	☐ motorcycle
	☐ car/pick up	☐ others………….
(14). Main reason to stay in the village	: ☐ close to the workplaces	
	☐ own an agriculture land	
	☐ own a house	
	☐ others …………………..	

3. Vulnerability indicators

Physical factors

(15). Floor material : ☐ soil ☐ cement

☐ wood ☐ tile/ceramic

(16). Floor condition : ☐ cracked floor ☐ no cracked floor

(17). Ventilation : ☐ poor ☐ good

Geographic factors

(18). Distance from Timbang crater : ☐ within radius 1 km

☐ within radius 1-2 km

☐ within radius 2-3 km

(19). House elevation : ☐ elevation is above Timbang crater

☐ elevation is below Timbang crater (downslope)

(20). Work location : ☐ in an agricultural land near Timbang crater (within 1km)

☐ in an agricultural land

☐ in an office/home

Human factors

(21) Health condition : ☐ all household members have asthma

☐ some household members have asthma

☐ all household members are healthy

(22). Health impacts : ☐ heart rate increased

☐ headache

☐ rapid breathing

☐ sweating

☐ vomiting

☐ unconsciousness

(23). Livelihood impacts : ☐ vegetable fields were affected by gas

☐ livestock were affected by gas

☐ losing job temporarily because of gas disaster

☐ losing job permanently because of gas disaster

☐ were not affected at all

4. Disaster Knowledge, Awareness, and Risk Perception

Disaster Experience and Disaster Knowledge

(24). Were you born in this village? □ Yes □ No

(25). How many times did you experience CO_2 gas disaster? ______ times

(26). How many times did you evacuate? ______ times
(27). Did you experience in the 2013 CO_2 gas disaster? □ Yes □ No
(28). Did you experience in the 2011 CO_2 gas disaster? □ Yes □ No
(29). Did you experience in the 1979 CO_2 gas disaster? □ Yes □ No
(30). Did you evacuate in the 2013 CO_2 gas disaster?
□ Did not experience □ Did not evacuate □ Evacuated
(31). Did you evacuate in the 2011 CO_2 gas disaster?
□ Did not experience □ Did not evacuate □ Evacuated
(32). Did you evacuate in the 1979 CO_2 gas disaster?
□ Did not experience □ Did not evacuate □ Evacuated
(33). Have you ever attended disaster mitigation training from government? □ Yes □ No

(34). How many training did you attend?
□ never □ once □ 2-3 times □more than 3 times

Awareness and Risk Perception (adapted from (Ho, Shaw, Lin, & Chiu, 2008)

(35). In the village you live, how likely is the likelihood that a CO_2 toxic gas will occur?
□ very small □ small□ large □very large
(36). Do you know clearly the mitigation actions you can do when disaster occur?
□not clear at all □ not really clear □ clear □very clear
(37). To what extent does the gas threaten your life?
□not serious at all □ not really serious □serious □very serious
(38). To what extent does the gas affect the quality of your life?
□not serious at all □ not really serious □serious □very serious
(39). To what extent does the gas bring you financial loss?
□not serious at all □ not really serious □serious □very serious
(40). In general, how afraid are you of the gas?
□not afraid at all □ not really afraid □afraid□very afraid

5. Coping Capacity

Coping Strategies in Physical Aspects

a.

b.

c.

d.

e.

Coping Strategies in Economic Aspects

a.

b.

c.

d,

e.

f.

Coping Strategies in Social Aspects

a.

b.

c.

d.

e.

Open key questions:

a. How long have you and your family lived in this village?
b. How many family members (people) are living with you?
c. What do you do on a typical day?
d. Where do you spend most of the day?
e. What are the main hazards in your village? (toxic gas, mudflow, or else)
f. Is there any history (from the past) about the toxic gas hazard?
g. How dangerous do you think CO2 toxic gas is?
h. What would you do if there were danger status coming from BPBD?
i. What are the hazard impacts on you, your family, or your community?

APPENDIX 2

QUESTIONNAIRE (2)

Researcher : Dwiyanti Kusumaningrum
Institution : Universitas Gadjah Mada
Research Title : Human Vulnerability and Coping Capacity Related to Carbon Dioxide (CO_2) Volcanic Gases in Dieng Plateau Central Java
Purpose : *This survey is intended only for scientific research purposes to study human vulnerability and coping capacity related to carbon dioxide in Dieng Plateau*

Questionnaire no : ____________________
Date : ____________________
Respondent's name : ____________________
Institution : ____________________

1. What organizations involved in Dieng volcanic gases hazard management? Which are other stakeholders and how do you work together?

____
____
____
______

2. How does the community cooperate with government and non-government organizations in disaster management?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10

3. What is the role of those institutions in volcanic gas management?

Institutions	Role in volcanic gases disaster management	Roles of institution: ☑ Risk assessment ☑ Prevention ☑ Preparedness ☑ Awareness raising ☑ Mitigation ☑ Warning/evacuation ☑ Saving victims ☑ Damage assessment ☑ Reconstruction ☑ ....

4. Would you please describe the role of your institution in volcanic gases management?

5. How effective does your institution in conducting your role in volcanic gases disaster management?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10

6. How is the communication among stakeholders when disaster occurs?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10

7. Is the data and information related to volcanic gases regularly distributed among stakeholders?

☐ Yes ☐ No

8. Is there any workshop or meeting between stakeholders involved in risk management?

☐ Yes ☐ No

9. How is the availability of equipment?

Gas masks	….
Oxygen masks	….
Gas measurement tools	….

10. How is the availability of service?

Shelters	….
Health care	….
Warehouse for emergency food	….
Clean water and electricity supplies	…
Evacuation route	….

11. Do you have toxic gas warning board at prone areas?

☐ Yes ☐ No If yes, Where? ……

12. Is there any renewal of volcanic gases risk map?

☐ Yes ☐ No If yes, How? …..

13. How is the disaster management in the past disaster (SInila 1979 disaster)?

Institutions	Role in volcanic gases management	Roles of institution: ☑ Risk assessment ☑ Prevention ☑ Preparedness ☑ Awareness raising ☑ Mitigation ☑ Warning/evacuation ☑ Saving victims ☑ Damage assessment ☑ Reconstruction ☑ ....

14. How is the existing disaster management compared to disaster management in the past (SInila 1979 disaster)?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10

15. Name the aspect that should be improved for strengthening the volcanic gases disaster management.

THANK YOU!