Statistical analysis of correlation between hazard-related factors and households' evacuation decisions in Mt. Merapi

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This study examines the hazard-related factors that influence households' evacuation decisions of communities living in Mt. Merapi, Yogyakarta, Indonesia. Data for the statistical tests (n = 322) were obtained from a survey carried out by the authors in January – February 2008 to the communities living at the southern flank of Mt. Merapi. In this paper, we tested the correlation between households' evacuation decisions and three hazard-related factors, namely: disaster experience, hazard proximity and natural signals of disasters. These three factors were set into several hypotheses which were tested using chi-square statistical tests. Significant relationships between these three hazard-related factors and the evacuation decision are found.

Key Words *: community, evacuation decision, hazard, Mt. Merapi, volcano*

1. Introduction

Evacuating people from a high risk area to a safer place has been an important issue in emergency situation. Successful evacuation management may be achieved if the emergency managers and local government correctly understand the evacuation behaviors of people at risk. Realizing it's importance, nowadays many research studies attempted to understand the evacuation behaviors of people at risk. However most cases indicated that many studies were carried out in the context of developed countries in particular at some hazards, such as floods and hurricanes (see the literature review carried out by Lindell and Perry 2004). Our case study, Mt. Merapi, illustrates the example from a developing country setting and the case of a volcano hazard, which is still understudied. Having this background, our study aims to address the gap on little research of evacuation behavior in the case of a volcano hazard and of developing countries.

Many interplay factors are realized influencing evacuation decisions by the households. These may include economics, socio-cultural, political situation (Wisner et al 2004) and hazards-related factors. In this study, however, we focused to carry out a systematic analysis based on factors related to hazards, namely: 'hazard proximity', 'disaster experience' and 'natural signals'. The working definition of factors used in this study refers to the definition which was used in other studies as proposed below. Hazard proximity includes the physical distance from the hazard source to the people's residence (Lindell & Hwang, 2008). Assumably, hazard proximity measures how people are exposed and in what way people are exposed to the source of hazards. In this respect, it assumes that the closer the distance of a place / a community to the source hazards, the higher the possibility it will be exposed to a hazard. As the case of volcanic eruption, the source may come directly from the materials erupted directly from the volcano (lavas, pyroclastic flows, ash falls and blasts) and when the materials flown through the channels or rivers (lahars abd debris) nearby that flow the lava from the volcano. In our study, we measure the direct physical distance from the hamlet to the source of hazards.

In our study, disaster experience includes people's experience of past occurrence of disaster which lead to casualties and damages which occurred to the respondent himself/herself and by members of the extended family (Lindell & Perry, 2004). However, this does not include the process of getting exposed to the news related to disasters (disaster education) or seeing the remaining hazard occurrence (field visit to a place previously hit by a disaster). Disaster experience can be related to the function of annual probability of the occurrence of major events and the number of years since the past exposure at the certain location.

The natural signals includes the physical cues that serve to alert the communities that a real threat appears (Lindell & Perry, 2004). McAdoo et al (2006) provided an an example of natural warning signals that reminded people living in Simeulue Island, Indonesia to climb up towards the higher land to escape from the coming tsunamis. Through this, the number of victims by the Indian Ocean tsunamis to people living in this island was considerably low as compared to the other affected areas in the region. In the case of a volcanic eruption, there might also be some natural signals that remind people prior to an emergency situation. If the people at risk understand this kind of phenomenon adequately and could make use such knowledge, it will help to increase people's awareness and thus reduce the disaster risk.

Based on the above arguments, we develop several hypotheses as follows:

- Hypothesis 1 (H1: Evacuation decision will be positively correlated with the distances to the source of hazards (hazard proximity). The closer the distance of the hazards to their house, the higher is their willingness to evacuate

from their house. Therefore, this hypothesis is separated into two: (H1a), evacuation decision will be positively correlated with the distance between the volcano and the hamlet where the respondents reside and (H1b) Evacuation decision will be positively correlated with the distance between the closest river that channels the lava and the hamlet where the respondents reside.

- (2). Hypothesis 2 (H2): Evacuation decisions will be correlated positively with people disaster experience. Therefore, people who have had prior disaster experience will likely to leave the disaster prone area or to take an early action should a disaster is likely to occur.
- (3). Hypothesis 3 (H3): Evacuation decisions will be positively affected by the existence of natural signals of the volcanic eruptions. As people live near the volcano, therefore this hypothesis assumes that some people will wait for the natural signals from the volcano before evacuate their houses. People who listen to the environmental cues will be likely to take action to evacuate from the hazards.

2. Study Area and Methods

Administratively, Mt. Merapi Volcano is located at the border of two provinces: Central Java and Yogyakarta Provinces. The easiest access to the volcano is normally reached from Yogyakarta City, the capital of Yogyakarta Province. Mt. Merapi is located about 25 km from the volcano at the north part of the capital province.

For the data collection process, we carried out a field survey in January – February 2008. The respondents selected for this study were those who lived in Pakem and Cangkringan Sub-Districts, two of the most affected sub-districts in the region. In total, we surveyed 322 respondents, but with the valid number 320 respondents (two missing values). The field survey was actually part of a larger research study which was aimed to understand many factors (traditional cultural beliefs and hazards related factors) that influence evacuation decisions (Sagala and Okada, in review) and social resilience of the communities (Sagala et al, in review). The set of the questions about factors related to hazards that might affect the evacuation decisions, which are used in the analysis of current paper, is presented at table 1.

Factors	Option (Scale)	
Evacuated in 2006	Yes (1)	No (0)
Distance to the volcano	< 6.5 km (1)	> 6.5 km (0)
Distance to the river	< 150 m (1)	> 150 m (0)
Experienced of disaster in 1994	Yes (1)	No (0)
Depended their decisions based on observation to the natural signals	Yes (1)	No (0)

Table 1 List of Main Questions

We carried out pearson statistical correlation between the factors analyzed in this study (see table 2). If the mean value is more than 0.5 it means more respondents answer "yes", while if the value is less than 0.5 it means more respondent answer "no". The pearson correlation values show the strength of the relationships between the factors involved in the analysis. In addition to the pearson statistical correlation, we carried out cross-tabulation analysis and chi-square tests.

3. Results and Discussion

Table 3 explains the distance between the hamlet and the distance to the volcano and the rivers. All the relationshipbetween household evacuation decisions and hazard factors, except natural signals, are significant (see table 2). Therefore, we can conclude that the household evacuation decisions are highly related with the hazard-related factors. The weak relationship between evacuation decisions with the natural signals means that not all respondents hold adequate hazard knowledge. The conclusion is also strengthened by the

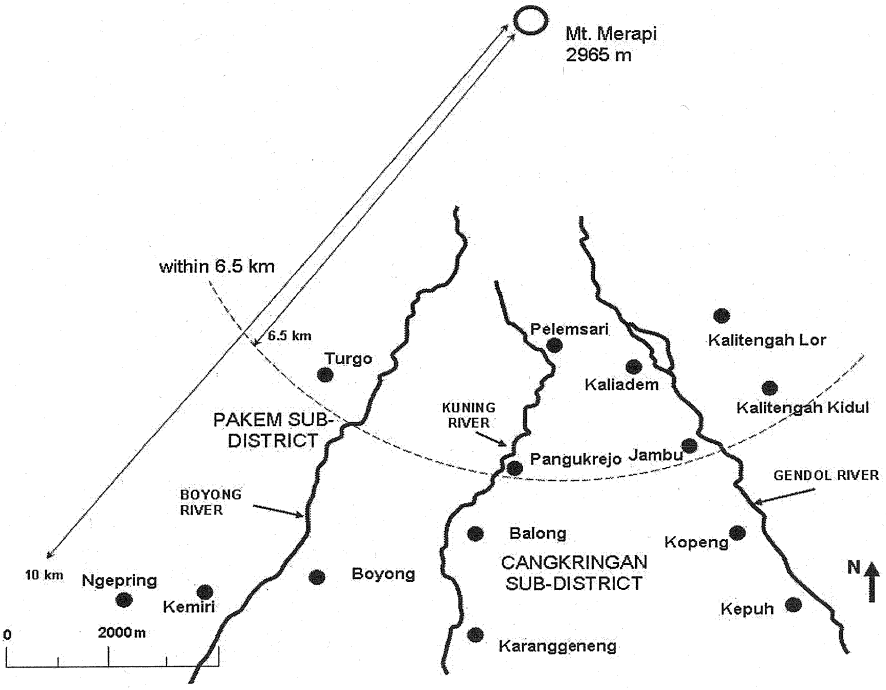

Figure 1 Study Area Location

fact that most of the relationships between evacuation decisions and natural signals are not significant, except for relationship to distance to river.

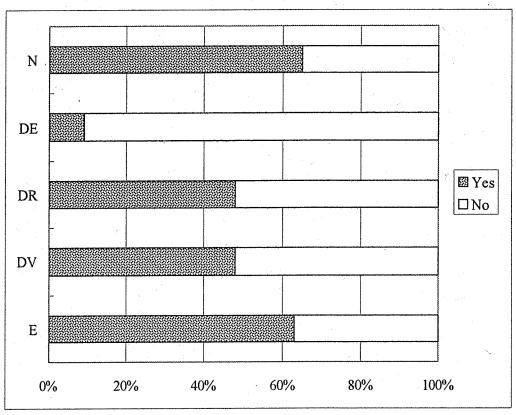

Figure 2 Values of Factors

The mean and standard deviation values of each factor is presented in table 2 and also illustrated on figure 1. Figure 1 explains the answers by the respondents to the list of questions mentioned in table 1. It indicates that most of the respondents (over 60%) evacuated in 2006 eruption and depended on natural signals prior to an eruption. An interesting fact which is presented in figure 1 is the fact that only a few respondents who experienced the volcanic eruption in 1994. When we further investigated the location of the respondents, we found out that the respondents were mainly Turgo hamlet, a hamlet which suffered victims in 1994 eruption.

	M	SD	E	DV	DR	DE	N
E	0.63	0.48	1				
DV	0.48	0.50	0.45**	1			
DR	0.48	0.50	0.20**	0.02	1		
DE	0.09	0.28	0.16**	0.32**	0.32**	1	
N	0.65	0.48	-0.06	0.08	0.12*	0.04	1

* significant at < 0.05, ** significant at 0.01

Meaning of Symbols: M: Mean, SD: Standard Deviation, E: Evacuation, DV: Distance to Volcano, DR: Distance to River, DE: Disaster Experience, N: Natural Signals

Table 2 Correlation of All Factors

The cross-tabulation and chi-square tests of all factors are described in the following four tables (see table 4, 5, 6, 7). The results of cross-tabulation analysis between the evacuation decision and proximity to source of hazards are presented in table 4 and table 5. Table 4 explains the relationship between household evacuation decision and the distance to the volcano. The pattern indicates that the closer the distance to the volcano, the higher the willingness to evacuate (132 people), while the further the distance to the volcano, the lower is the willingness (96 people). Thus, it confirms our hypothesis (H1a) that there is a significant relationship between people's decision to evacuate and the distance of hamlet to the volcano ($\chi 2$ = 65.078, df =1, p = 0.000). This is also proven by the chi-square test. This result suggests that those who are physically exposed to the hazard, in term of distance, are more likely to take decision to evacuate. This finding explains that people assess how their residence are exposed to the source of possible hazards. The relationship between evacuation decision and disaster experience is also significant (H2). This finding is confirmed by the result from pearson correlation and the chi-square test (table 6). However, the relationship between evacuation decision and natural signals is not significant as suggested in table 7.

No	Hamlet	Evacuation in 2006 (%)	DV (km)	DR (m)
1.	Turgo	89	6	150
2.	Ngepring	23	9	500
3.	Kemiri	16	9	175
4.	Boyong	35	9	100
5.	Pelemsari	33	5	150
6.	Pangukrejo	86	6.5	150
7.	Balong	0	8.5	300
8.	Karanggeneng	24	10	400
9.	Kaliadem	80	5.5	200
10.	Jambu	90	6.5	150
11.	Kopeng	96	8	150
12.	Kepuh	87	9.5	150
13.	Kalitengah Lor	100	5	300
14.	Kalitengah Kidul	94	6	250

Table 3 Distance from the hamlets to the volcano and river

		Evacuated in 2006		
		Yes	**No**	**Total**
DV	< 6.5 km	132	22	154
	> 6.5 km	70	96	166
	Total	202	118	320

Table 4 Evacuation Decisions and Distance to Volcano
(χ^2 = 65.078, df =1, p = 0.000)

		Evacuated in 2006		
		Yes	**No**	**Total**
DR	< 150m	113	41	154
	> 150 m	89	77	166
	Total	202	118	320

Table 5 Evacuation Decisions and Distance to River
(χ^2 = 13.403, df =1, p = 0.000)

Taken together, distance to the volcano and distance to the river conveys that proximity to hazard sources has been found to be also a factor of people decision to evacuate. Nonetheless, the knowledge on presence of environment does not always mean a full comprehension of the environmental phenomenon, including the risks. Noteworthy to mention also that this knowledge should be supported by enough information of potential risks involved. For example, during in depth interview in Kaliadem Hamlet, some respondents reported that they came closer to Gendol River, instead of running away, to observe the pyroclastic flow in the 2006 eruption. Fortunately, the pyroclastic flow filled up the upstream of Gendol River and did not continue to surge to the nearby hamlets.

The evidence of a significant relationship between disaster experience and decision to evacuate is important since it indicates the community takes lessons learned from prior experience and increases their awareness of the imminent volcanic risks. This finding supports the previous arguments, on the strong relationships between disaster experience and disaster preparedness, which was carried out in other countries, such as in United States (Lindell and Hwang, 2008). If this finding is true in general, it is expected that people who are exposed to a disaster would be more willing to evacuate should a disaster occur.

On the other hand, having a focus on disaster experience alone as a factor related to the decisions to evacuate could be misleading. If the previous disaster was at high risk or claimed many casualties and injuries, people would consider the future disasters as a high priority as what has happened in Turgo hamlet. Thus, people tend to be more alert to disasters than before (Lindell & Perry, 2004). However, if a past disaster previously hit at a small intensity and posed a small risk, risk perception would tend to decrease (Paton, Smith, Daly, & Johnston, 2008) and this would let them less aware to the next disaster. For example, the Merapi eruption in 2006 did not claim a huge toll in terms of loss of life and might decrease the people risk perception of the future eruption.

		Evacuated in 2006		
		Yes	No	Total
DE	Yes	24	3	27
	No	178	115	293
	Total	202	118	320

Table 6 Evacuation Decisions and Disaster Experience
($\chi^2 = 8.409$, df =1, p = 0.000)

Inconsistent with our initial hypothesis 3, the relationship between evacuation decisions and the natural signals are not significant. Even so, some still respondents mentioned that they depended on the natural signals of the volcanic eruption before evacuating from the danger. For example, respondents in Kalitengah Lor hamlet reported that many heads of the households would wait for signals in the form of huge sounds, tremors, high temperature, and dark clouds before they decided to evacuate. If a cloud visualizing a sheep-like occurred, they will immediately evacuate since it is the common signs of the pyroclastic flows (obtained from interview to respondents in Kalitengah Lor, 2008).

The finding on the reliance of some people on the natural signals (sound, sight, temperature, etc) prior to an eruption is important (H3). In the absence of official warning, maintaining this knowledge is good and crucial because people can take immediate action or leave the danger place. For example in 1994 eruption, Paripurno et al (1999) reported that the Turgo residents observed the above phenomenon yet did not leave the place because they had not had such knowledge earlier. Depending on this knowledge alone could be unsafe since a pyroclastic flow might be developed immediately after the natural signals occur. Therefore it is important to integrate this knowledge with the existing volcanic warning systems.

		Evacuated in 2006		
		Yes	No	Total
NS	Yes	126	81	207
	No	76	37	293
	Total	202	118	320

Table 7 Evacuation Decisions and Natural Signals
($\chi^2 = 1.281$, df =1, p = 0.258)

5. Conclusion

The overall findings in the previous section point out that in this study, hazards related factors (disaster experience, hazard proximities and natural signals) play dominant roles in influencing people's evacuation decision. These findings are important since they illustrate that the communities in Mt. Merapi also take action as what found in research studies which relates evacuation decisions and hazards related factors. The results of this study largely contribute to the understanding of evacuation decision among few literature in this topic in the context of developing countries. The similar finding obtained in this research shares findings with research in developed country (Lindell & Perry, 2004) that evacuation decisions are significantly related with hazards related factors.

Our study found that the household evacuation decisions are mostly affected by two factors: distance to hazard sources (volcano and river) and disaster experience. A weak correlation is found between the household evacuation decisions and natural signals. The results of this study imply that the respondents or residents at the southern flanks of Merapi took the hazard-related factors to their consideration. This means, if the government requests an evacuation when there is an increasing of the volcanic activity, some residents still will consult to their current condition.

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