Chapter 9

# Disaster Mitigation Model of Eruption Based on Local Wisdom in Indonesia

Eko Hariyono and Solaiman Liliasari

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.79217

**Abstract**

Kelud is one of the most active volcanoes in Indonesia and suffered a major eruption in 2014. Although they are not part of the super volcano, the impact of the eruption is extraordinary. However, the eruption is not too worrying for the surrounding community. The lack of disaster victims caused by the eruption in 2014 became a successful representation of disaster mitigation models owned by local communities in answering the eruption problem. The easy evacuation process and quickly post-eruption rehabilitation illustrate a pattern of environmental adaptation around the volcano. This discussion focuses on how the people behavior around the volcano in responding to the challenge of eruption? How the role of local government in preparing the community in the face of an eruption, and what actions are done so that the rehabilitation process can take place quickly? To answer all these questions, the researchers collected relevant data through observation, documentation, and interviews with the local communities and local government representatives directly involved in disaster mitigation measures. In addition, the researchers also revealed local traditions that are considered capable of supporting the process of preparing the community in answering the eruption challenges and becoming part of disaster mitigation in the volcanic region.

**Keywords:** disaster mitigation model, volcanic eruption, natural disaster, local wisdom in Indonesia

## 1. Introduction

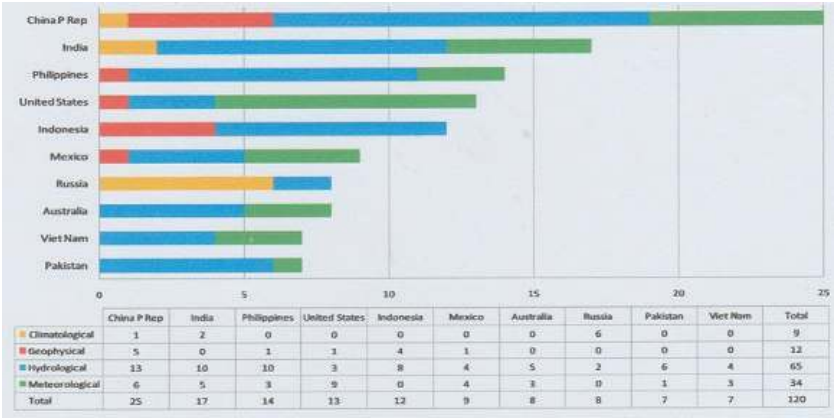
Indonesia is one of the countries in the world most vulnerable to natural disasters and climate change [1]. Based on the world disaster statistics accessed from Centre for Research on the Epidemiology of Disasters (CRED; **Figure 1**), Indonesia ranks fourth after the Republic of

China Province, India and Philippines in terms of geophysical disasters [2]. This is due to the location of Indonesia in the equatorial region and is at the meeting of three giant plates (Pacific, Indo-Australian and Eurasia). In addition to the fertile land of agriculture, beautiful scenery and great geothermal potential, the negative impacts are occurrence provided various geological disasters such as earthquakes, tsunamis, volcanic eruptions and landslides [3]. The consequences of the geological disaster caused terrible human casualties, social and economic losses and environmental damage [4].

The various of natural disasters that struck Indonesia demanded the people to be ready, responsive and alert. The presence of hundreds of active volcanoes as a consequence of Indonesia be a part of the Ring of Fire, it should be a sign that the terrestrial disaster can be present at any time and everywhere and become a threat to the community. An effort to build a safe life against for people in disaster area becomes a challenge for the government and the people of Indonesia. Through the improvement of the volcanic disaster program of monitoring and communication system and community preparedness planning will be able to minimize disaster risk [5].

A disaster is a traumatic event that has the potential to inflict injury and even death [6]. Among natural disasters, volcano eruption is considered the most dangerous natural disaster [7]. The eruption catastrophe greatly affects the people, both directly and indirectly [8] and gives various impacts to the surrounding environment and society [9, 10]. The eruptions can also causes other disasters, like volcanic earthquakes, tsunamis, the change of weather and climate that caused by increased concentrations of aerosols in the earth atmosphere [11, 12].

Based on the history of volcanic eruption, Indonesia had experienced the biggest eruption in the history of the world. The Krakatau eruption in Java (1883), Tambora in Flores (1815) and an eruption of super-volcano Toba rebellion in 76,000 years ago [13] with terrible impacts on a local, regional and global scale [14]. The eruption of Tambora with the death reached 92,000 people and caused global climate change that known as "The year without summer." This




| | China P Rep | India | Philippines | United States | Indonesia | Mexico | Australia | Russia | Pakistan | Viet Nam | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Climatological | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 9 |
| Geophysical | 5 | 0 | 1 | 1 | 4 | 1 | 0 | 0 | 0 | 0 | 12 |
| Hydrological | 13 | 10 | 10 | 3 | 8 | 4 | 5 | 2 | 6 | 4 | 65 |
| Meteorological | 6 | 5 | 3 | 9 | 0 | 4 | 3 | 0 | 1 | 3 | 34 |
| Total | 25 | 17 | 14 | 13 | 12 | 9 | 8 | 8 | 7 | 7 | 120 |

**Figure 1.** Indonesia ranks fourth in geophysical disasters after China's Republican Province, India and Philippines [2].

eruption impact is the occurrence of a prolonged winter in Europe and northeastern North America for 1 year [15]. The eruption of Krakatau caused victim more than 36,500 people and caused tsunami in coastal Java and Sumatra [16, 17]. Another major eruption was the eruption of Galunggung in West Java in 1822 with the death toll of 5500 people and Mount Agung in Bali in 1963 with a total victim of 1900 people [18].

The great eruption that occurred in the last decade was the eruption of Merapi. As the most active volcano in Java [19], its eruption always accompanied by lava bursts and pyroclastic flows along as several kilometers [20]. Due to the eruption, approximately 339 people died [21, 22]. The magnitude of the victims of Merapi eruption is caused by the increasing population of the people living around the volcano, so that when the disaster occurrence causes multiple casualties [23].

The biggest eruption challenge in the last decade in Indonesia comes from the Mount Sinabung in Karo province of North Sumatra. This volcano has the last eruption around the year 1200 and back to erupt in 2010 [24], and continues to the present [25]. Sinabung eruption strength is smaller than Merapi [26], but it caused the extraordinary economic losses of IDR 42,796 billion (USD 3295 million) [27].

In general, the Indonesian people are less ready to face the volcanic eruption disaster resulted from the lack of knowledge in preparing for disaster [28]. This is caused because of the fact that the public does not understand the impact of the eruption and low skill in planning and preparing for the volcanic activity [29]. Knowledge is a key factor for the community in understanding the process of natural disaster, so it will be calmer in facing it [30]. However, the public awareness of the environment around the volcano is also very important to the readiness of society in facing eruption disaster [31].

Various experiences of the eruption faced by the Indonesian nation prove that the Indonesian people are very strong in facing the natural disaster. Many efforts have been made to improve the resilience of communities [22]. Although recorded in history is not a few victims of volcanic eruption disaster, but the community has been survived in the vicinity. The eruption has built the emotional closeness of people who experience the same disaster. Traumatic events due to volcanic eruption can improve both social and individual of the community life [21].

Along with the development of time, Indonesian people matured in seeing the eruption disaster. They realize that the eruption disaster is God's will that cannot be prevented but also need not worry too much in facing it. Success in the face of disaster is determined by the ability to adapt to the environment [32]. Building a life in harmony with nature is the key to success in addressing all the challenges of natural disasters and the Indonesian people have presented it in the form of local wisdom. A jargon "Disaster brings blessings" always conveyed by the local government in motivating people to remain grateful for all the calamities that hit make the community stronger in the face of disaster. This jargon implies that the eruption is not only seen from the negative side of the damage, but the blessing behind the eruption disaster is much greater than the damage received [33]. Increased fertility of the soil as a result of volcanic ash [34] becomes one of the blessing forms of an eruption which can be used as a soil stabilization material [35]. This is a promising prospect for the communities around volcano who are mostly farmers.

Integration with local wisdom is very important in an eruption disaster mitigation because cultural roles in local wisdom are proven crucial in disaster risk reduction, but in the planning of disaster risk reduction strategies is often largely be ignored [36]. Therefore, it becomes a consideration of the need to integrate local wisdom in developing a new design of volcano mitigation model based on local wisdom that is assessed the most appropriate to the condition of Indonesian people.

## 2. The various experiences of eruption of several volcanoes in Indonesia

Mount Kelud is one of the stratovolcano that became proud of the community of East Java Indonesia. An active volcano with an altitude of 1731 m above sea level is located at 7°56′00″ SL (South Latitude) and 112°18′30″ EL (East Longitude). This mountain is produced from a subduction process between the Indo-Australian and Eurasian plates in the south of Java Island [37]. The magnificence of Mount Kelud is increasingly visible because it is flanked by three volcanoes that are currently in a resting condition, namely Mount Wilis in the West, and in the east, there is a complex of Mount Kawi and Butak. From a distance, Mount Kelud looks like a stunning natural building with tremendous geographic and geological potential.

Geographically, Mount Kelud is located in three districts, namely Malang, Kediri and Blitar (**Figure 2**). In addition to storing a variety of beauty, Mount Kelud promises a good life for the surrounding community. The fertile volcanic soil around Kelud makes the land in this mountainous region very good for developing agriculture industry and a variety of productive local plants to support the improvement of the welfare of the surrounding community.

Based on monitoring results from the volcanology center, Mount Kelud has three eruption characteristics, namely semi-magmatic, magmatic and effusive. Semi-magmatic eruption is a phreatic eruption triggered by evaporation of crater's lake water that seeps through a crack at the bottom of the crater and exhaled to the surface. This eruption started the magmatic eruption. The magmatic eruption is the eruption followed by the exit of volcanic material

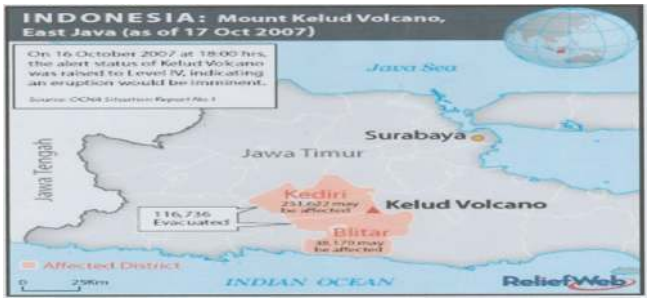



**Figure 2.** Kelud location map in East Java and the impact of its eruption in 2007 (https://volcano.si.edu/volcanoes/region06/java/kelut/3303kel7.jpg).

from the body mountain. These eruptions are generally explosive due to increased volcanic gas and eruptive energy. The effusive eruption is an eruption accompanied by magma flow to the surface that can form a lava dome [37]. Based on **Figure 2**, the 2007 eruption had a major impact on residents in two districts, 251,622 residents in Malang Regency and 38,170 people in Blitar Regency. The total evacuation reached 116,736 people.

Mount Kelud has experienced seven times of eruptions during 1900–2015, that is, in 1901, 1919, 1951, 1966, 1990, 2007 and 2014 with the decreasing number of fatalities (**Figure 3**). The latest eruption of Mount Kelud occurred on 13 February 2014 with a level of an eruption (VEI) is quite powerful to be able to vibrate the Earth's ionosphere layer. Volcanic ash bursts are expected to reach a height of 17 km with 76,000 people evacuated [38]. As informed from PVMBG, the eruption characteristic of Kelud 2014 is different from the previous eruption (1990). The eruption in 2014 has a considerable impact on a number of big cities in Java.

In addition to storing geological potential and extraordinary natural charm, Mount Kelud also has the substantial potential disaster after an eruption that must be wary of. The Kelud people called cold lava flood (**Figure 4**). This disaster is no less terrible than the catastrophic eruption. The characteristics of Kelud's lava are quite unique. Basalt-andesitic lava type with relatively middle silica content makes the distribution not sufficiently extensive or only in the center of the eruption and its surroundings. However, the presence of post-eruption rain around the volcano causes the lava that mixed with other eruption material to be carried over several kilometers by the flow and destroying the area around it. Besides causing casualties, the lava floods making the breakdown of communication lines and some areas around the mountain become isolated.

One of the characteristics of Kelud eruption is very horrible and accompanied by a roar and thundering. The eruption is also accompanied by terrible lightning flashes due to the process of

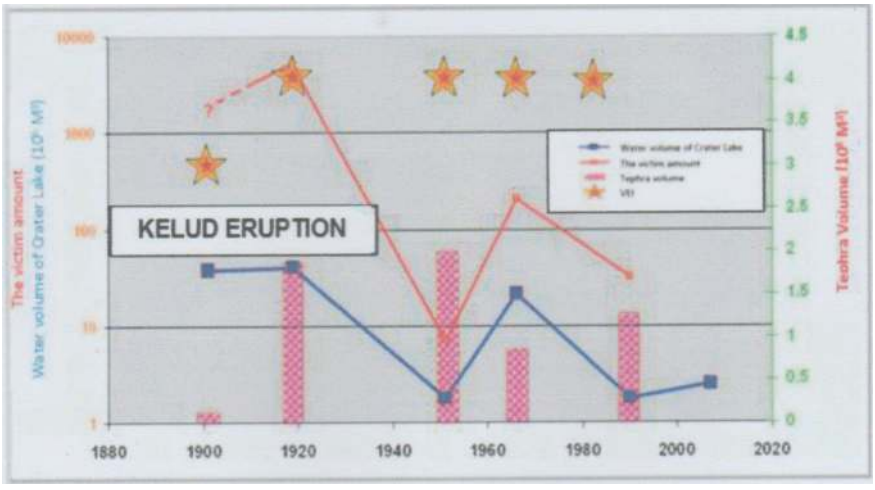



**Figure 3.** Kelud eruption profile since the eighteenth century. This graph shows the relationship between the volume of crater lake water and the number of fatalities (modified from: https://geologi.co.id/2007/11/05/bagaimana-letusan-kelud/).


**Figure 4.** The cold lava flood. Another terrible disaster that following of Kelud eruption (https://www.merdeka.com/foto/peristiwa/323649/20140218200905-dahsyatnya-banjir-lahar-dingin-gunung-kelud-001-debby.html).

ionization of clouds caused the electrical charges carried by the volcanic ash into space and in contact with other charges in the atmosphere. The combination of electric flashes and a puff of ash into the sky displays a gigantic figure that is terribly believed by local people as the incarnation of Mount Kelud who is angry (**Figure 5**). This condition is used by the local government in instructing people to immediately leave from dangerous areas around Mount Kelud.

Although its eruption is assessed by geologists as a powerful eruption, it does not mean cause the occurrence of many casualties. This condition illustrates the success of disaster mitigation actions implemented by local communities and Kediri regency government. The government works collaboratively with local communities to help protect communities from the physical and psychological impact [39].

Besides Kelud, Mount Merapi (2986 m asl) is one of the legendary mountains in Java Island. Geographically, Mount Merapi lies on 7°32′30″ SL and 110°26′30″ EL, bordering four districts,

**Figure 5.** Kelud eruption in 2014. The combination of electric flash and volcanic ash resembles an angry gigantic figure.

namely Sleman in Yogyakarta and Magelang, Boyolali and Klaten in Central Java Province (**Figure 6**), as a subduction product between plates Indo-Australia and Eurasia in Java [37]. The historical record of Merapi eruption began in 1768. From that time until now, Merapi has erupted 80 times with varying strength and periodization [37]. The eruption impact not only caused a lot of casualties and environmental damage but also deep trauma for the people living around it [40].

The large eruption of Mount Merapi in the last decade occurred in 2010. This eruption is considered the largest eruption since 1870 with the death toll reaching 277 people [21]. Although the same type of stratovolcano like Mount Kelud, the eruption characteristics is different from Kelud. Merapi eruption characteristic is lower explosive with eruption index level between 1 and 3. Merapi rocks are basaltic-andesitic [41] with silica ($SiO_2$) content of 52–56% (greater than the silica content of Kelud volcano). However, it does not mean that the Merapi eruption is safe for people living around it.

The volatile material of Merapi cause in every eruption always followed by a lava dome [42] that produces hot clouds or "Wedus Gembel" and greatly endangers the surrounding population. Hot clouds Merapi glide has a speed of 200 km/h with temperatures reaching 1000°C, with decreasing temperature between 23 and 27°C/km [43]. This hot cloud is a vertical pyroclastic flow explosion product [44] and flows gravitationally along the leaf and rivers and will stop when its energy is exhausted [38]. Recorded by BNPB, Merapi's biggest victim was inflicted by the hot clouds that attacked the settlements (**Figure 7**).

The ancient of Javanese believes, people believe in the relationship between Merapi, Keraton and the South Sea Ruler [45]. They believe that the Mount Merapi has supernatural powers


**Figure 6.** Merapi location map and settlement around it (wikipidia.org).

**Figure 7.** Hot clouds of Merapi or "Wedus Gembel" should destroy the surrounding settlements.

that can affect the lives of surrounding communities [46]. Merapi eruption always associates with the anger of the spirit of guardians; therefore, people on the slopes of Merapi are always careful in every attitude, words, and deeds and always maintain the hereditary traditions that are considered capable of muffling the anger of it.

The people around Merapi have ecological wisdom in terms of rearing, farming and living [47]. Before starting agricultural activities, the average community organizes a salvation event that aims to ask for blessing and safety in farming. To get fertile agricultural land people are advised to use a sharp machete to open the forest and use the intercropping system in farming. This can keep the soil fertility level. In the livestock system, the people of Merapi take grasses of feed animals in places that are considered not haunted. They went to the forest together and guarded each other against the disturbance of the spirits around Merapi. This is very impacting on the forest around Mount Merapi stay awake. At the time of taking grasses food in the forest which is considered haunted, the community must keep the environmental ethics. The wisdom of people in living is also owned by the people of Merapi. All buildings should not face Mount Merapi and Merbabu as it is deemed disrespectful to both mountains.

The story of Merapi eruption cannot be separated from the role of the figure of public figures who became the icon of obedience to the existence of volcano. He is Mbah Marijan, a caretaker who devotes his entire life to the Merapi volcano to become a victim of Merapi eruption malignancy in 2010. Communities around Merapi tend to be more obedient to the status information of volcanic activity from caretaker Mbah Marijan compared with information from the government. Although for sometimes the eruption experience is accurate, but not able to provide guarantees for the community because the decision taken by the caretaker is not based on proper geological studies. As a result, it is not a few casualties from the last eruption in 2010.

However, this does not mean that this experience is a bad history of the Indonesian people in facing the threat an eruption of Mount Merapi, especially for the people of Yogyakarta and its surroundings. The low level of public knowledge of the geological information presented in the technique is still difficult to understand, so there is a need for tools to communicate to the community related to volcanic activity. The contribution of Mbah Marijan with his experience in dealing with eruptions is considered very large in helping save the people from the Merapi eruption.

## 3. Community behavior and the challenges of volcano eruption

The volcano disaster provides a meaningful example of how communities apply cultures, religions and ceremonies to communicate and remember disaster risks and mitigation strategies [45]. The understanding of that society has based only on myth and not based on scientific knowledge so that the existence of the culture is not widely understood by the public. Therefore, it is necessary to conduct an in-depth study related to the culture of the community and local knowledge as material for the development of disaster mitigation model that is more suitable to the characteristics of the local community on the mountain slopes.

Communities located in disaster-prone areas are suspected of having traditional intelligence in dealing with disasters formed from the introduction of the physical environment [48]. Local knowledge of the environment around volcano plays a significant role in the impact of the eruption disaster [31]. As did Sugihwaras society in predicting eruptions based on changes in natural signs. People believe that if a python is present at the villagers' means Kelud volcano will soon erupt. The python is believed by the villagers as a mountain guard manifestation that conveys the message that "celebration" will begin soon and remind people to move temporarily. The people of Kediri also abstain from cutting down Bamboo trees and Banyan at random because they are considered as sacred trees. Both trees are very important in maintaining the quality of water and soil in the surroundings of Mount Kelud.

The history of Mount Kelud and Merapi eruption, as well as several volcanoes in Indonesia, cannot be separated from the traditions of the surrounding community. A belief that the eruption of a volcano is a manifestation of the anger of the mountain guard makes the community always obedient to the tradition to perform the ceremony of honor. Scientifically, this context is very unusual, but adherence to local traditions and cultures provides a distinct advantage for people to remain secure in the face of volcanic eruption threats. One of the evidence is an offering performed by the community around Kelud mountain on 1 Suro (Javanese month). Based on the field study, most of the people of Kediri (82.61%) consider the offering ceremony to be important. One of the reasons is to obtain salvation from God Almighty from the danger of Mount Kelud eruption (65.22%). The spiritual power makes people feel secure and protected from natural disaster [21]. The culture role is very important in disaster risk reduction because through the power of culture is able to reduce the vulnerability of society to disaster [36].

This finding is highly relevant to the results of the previous study. The communities around the volcano have their own way of dealing with the threat of eruption. They have developed a system to live around the volcano through naturalization, familiarization and domestication toward all threats from volcanoes [19]. Various forms of ritual are carried out by communities around the volcano which aims to respect the volcano that seen as a source of life [49]. People consider that the volcano is a part of their daily culture and life. They have a unique culture that portrays volcano as the center of the God and the symbol of greatness [33].

Local wisdom is a basic knowledge that achieved in the balance of life with nature and related to the culture in the community with its main character is that wisdom comes from experience or truth derived from life [50]. A ritual ceremony is a form of local wisdom as it connects the balance of nature with life. The main purpose of this ritual is to express gratitude to God Almighty who has given the fertility of the land in the mountain of Kelud and Merapi and

so that people avoid the eruption disaster. This ritual is a cultural framework that reflects the social structure and provides a sense of security like their ancestors [51].

The wisdom of the people around Kelud is also visible from the house building designed to minimize the impact of the eruption disaster. Various types of houses are built with small size and have a sturdy pole and a tapered roof (less than 45°) (**Figure 8**). This is done with the consideration of volcanic ash will more easily fall to the ground, so that the house does not become collapsed due to support a load of ash erupted. In addition, the community uses roof tile from clay. They believe that the clay is more weather resistant both in the rainy season and drought and more environmentally friendly. The use of clay tile is very suitable for settlement in the mountains because it can stabilize the temperature inside the house so it remains warm and comfortable.

The ability of communities around the volcano in the face of the eruption disaster becomes a model that can be developed in different regions with the same geological background. Differences in social, cultural and economic factors play an important role in the ability of communities to understand disasters and how they cope with disaster risks [51]. Like the Tenggerese people of the Bromo Mountains, they have five cultural adaptations that enable them to survive in the mountainous areas of resilience and high ability to return to their original state, attachment to place and knowledge of danger, the source of social and moral order, and catalyst for the process of change [33].

Compliance with the traditions and beliefs against the signs of nature helps the people to save themselves from the dangers of an eruption. But the traditions of the people and the signs of nature have not been studied scientifically, so that they cannot be understood by the wider community. Although people have an indigenous knowledge and use it daily, they are not aware that it can be used to reduce disaster risk [52].

The natural environment around the volcano determines the natural conditions for animals and plants in it. This illustrates the importance of preserving the environment. At a time when the environment is disturbed, the animals and plants can longer serve as a messenger

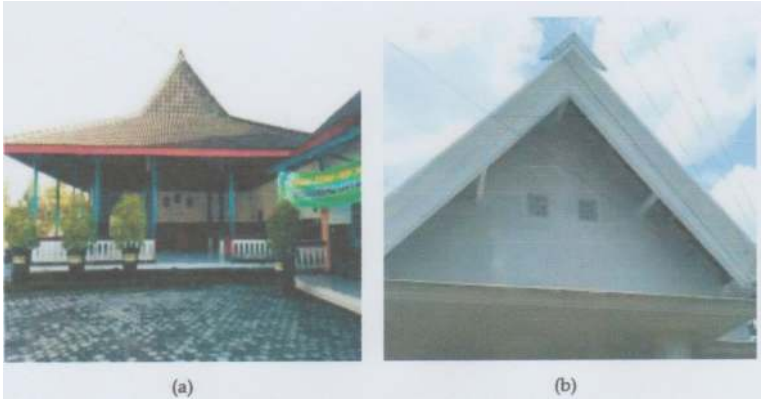



**Figure 8.** The changes of residential model around mount Kelud. (a) Joglo-shaped roof commonly called the "Tuo" building form and (b) the roof of a cone-shaped house is commonly called the "Enom.".

of nature against the disaster. The abstinence of not wearing red shirts on the slopes of Kelud, ringing the whistle with the mouth to produce high-frequency sounds, not destroying the environment around mountain, and not doing immoral acts is essentially an ethno-pedagogy to keep the environment order to stay natural and sustainable. When the natural conditions are well preserved, then nature will work in accordance with its role.

Success in facing the danger of eruption is not just the success of the government alone, but the wisdom of society in protecting the environment and building a life in harmony with nature makes the impact of the eruption is not so influential in the community. Evacuation and recovery process that runs quickly to make people can survive the eruption disaster and his life can be restored quickly as usual and even better. There are two patterns of adaptation conducted by communities around the mountains of Merapi, the pattern of economic-ecological adaptation and magical belief [53].

A comprehensive system of risk management and preventive measurement is essential in order to reduce potential losses from disasters [39]. Reducing disaster risk requires an integrated approach between social science and the natural sciences [28]. The integration of local knowledge and ethno-science approach into a contemporary framework for the conservation and sustainability of natural resource management will be increasingly important at both national and international levels, especially in developing countries [54].

## 4. Disaster mitigation model based on local wisdom

The decreasing number of deaths due to eruption from year to year show the disaster management techniques carried out by the government through the National Disaster Management Agency or Badan Nasional Penanggulangan Bencana (BNPB) are better, although not balanced with the level of public awareness in maintaining the environment as an effort to minimize the disaster risk. The high environmental damage caused by some people who are not responsible to be one of the factors triggers the high risk of geological disasters in Indonesia. The low public awareness of the dangers of eruption is a serious concern as a matter to be solved. Not only the responsibility of the government, but also the entire community. All government, non-governmental and international organizations have responsibilities in disaster recovery programs with mutual cooperation between them and the community [55].

Dealing with eruption problems, the government selected effective measures, such as land use arrangements, lava control systems, development of monitoring and early warning systems, evacuation plans, relocation of the population and education and community preparedness programs [4]. By synergizing local wisdom and government programs, disaster mitigation plans can be well implemented.

Disaster mitigation is an effort by the government and the community as an action to minimize disaster risk. This is because volcanic hazards can cause total destruction of the path through which pyroclastic material flows, so that communities must be temporarily displaced. However, the implementation of mitigation is not as easy as imagined. Not all

communities living around the volcano are willing to be evacuated even though disaster early warning has been submitted by the government.

Often people do not understand the geological information presented by the government, but the public better understands the environmental changes of the natural signs. This fact reinforces the need to integrate geological information and local wisdom in making accurate decisions to face of natural disasters. Successful experience in dealing with earthquake and tsunami disaster for Simeulue-Aceh community proves that local wisdom is very important in minimizing disaster risk. They have a way of responding to disaster challenges through traditional communication tools, construction methods and residential planning, and traditional ceremonies [56].

Based on the results of field studies that have been conducted on communities around Mount Kelud associated with disaster mitigation measures, 36.36% said they chose to be evacuated. This means no less than 60% of people still choose to live in the area of disaster eruption. In the vicinity of volcanoes, innovation in disaster mitigation models is required by incorporating local wisdom in it. This needs to be done so that mitigation and recovery process can be quick and easy [56].

**Figure 9** is a model of a local wisdom-based disaster mitigation plan implemented in the village of Pelem Sari Yogyakarta. This model integrates the local wisdom in responding to Merapi eruption disaster and very interesting to discuss. Based on the picture, local wisdom serves as a traditional signal when the eruption does not suddenly erupt. There are conditions that have not been able to be completed especially at the time of Mount Merapi erupted suddenly and accompanied by a dangerous eruption. In these circumstances, the main priority is the safety of the population and necessary hard efforts from the government to take a quick decision for evacuating people immediately and leave dangerous areas to get to the safest location as quickly as possible.

Related to the development of volcanic disaster mitigation model, we can learn from Maori indigenous people by integrating local, science and art. They have three important steps: (1) communication understanding of geological and volcanic processes from different perspectives, (2) optimizing local communities living around the volcano to improve preparedness, and (3) develop learning tools for current and future generations that can be used in various community levels [49].

There are four approaches to consider in assisting communities in reducing disaster risk based on local wisdom, including (1) understanding, communicating and managing vulnerabilities and risks and perceptions of local communities about risks and vulnerabilities that come to threaten the life of the community in the future, (2) maximizing community benefits about volcanic environments, especially during rest periods without increasing vulnerability, (3) managing crises, and (4) managing settlements after the crisis [57].

Reducing disaster risks related to efforts to improve community resilience that can be implemented through the preparation of disaster mitigation plans [32]. A comprehensive system of risk management and preventive measurement is essential in order to reduce potential losses from disasters [39]. Reducing disaster risk requires an integrated approach between social

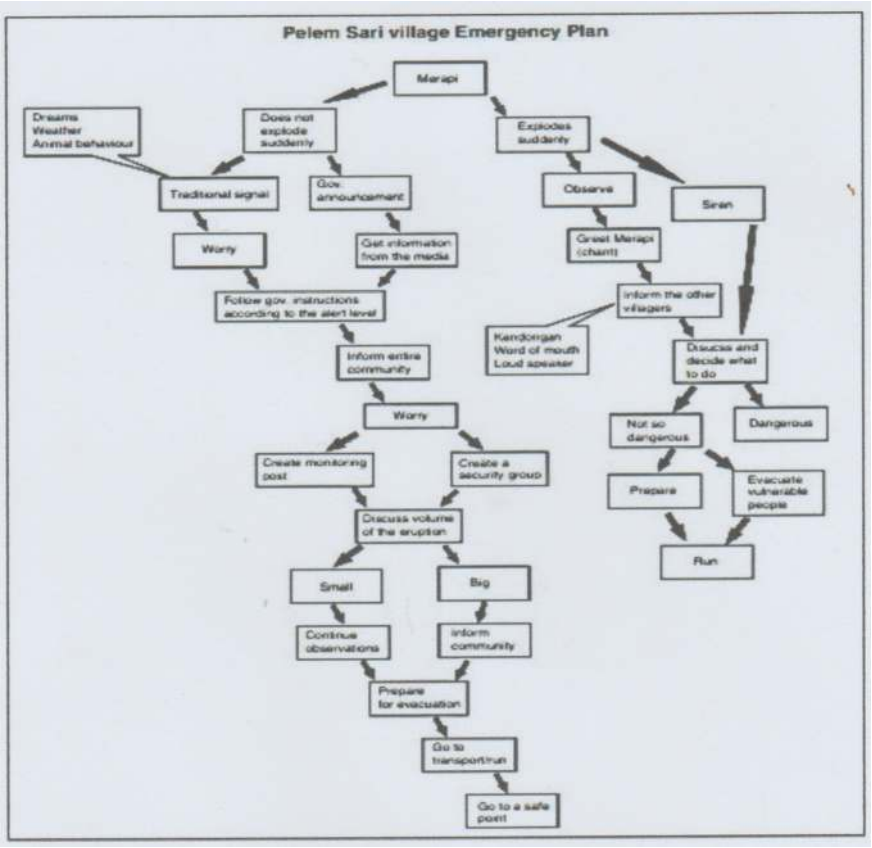



**Figure 9.** A model of a mitigation plan that integrates local wisdom in the Pelem Sari village Yogyakarta [36].

science and the natural sciences [28]. The integration of local knowledge and ethno-science approaches into a contemporary framework for the conservation and sustainability of natural resource management will be increasingly important at both national and international levels, especially in developing countries [54].

Success in disaster mitigation is strongly influenced by the experience and local knowledge of communities in the face of disasters [58]. Community knowledge is acquired from within and outside the community as a way of dealing with problems [50]. The ways in which the community represents knowledge in dealing with disasters become the local wisdom of the local community. The integration of traditional knowledge and scientific knowledge will get an overview of how to engage communities in vulnerability and risk management [57]. Natural environment around the Kelud Mountain determine the natural conditions for animals and plants in it. This illustrates the importance of preserving the environment. At a time the environment is disturbed, the animals and plants can no longer serve as a messenger of nature against the disaster.

Technology is not the only tool capable of ensuring the safety of people around the mountain, but technology needs to be supported with the local knowledge of people who have more experience related to the surrounding environmental conditions. This became a recommendation in developing a model of volcanic disaster mitigation although in the millennial era. The combination of traditional knowledge and scientific knowledge resulted in a new pattern in addressing disaster challenges and making communities more actively involved in disaster risk management [57].

## 5. Conclusion

The fruitfulness in facing volcanic eruption in Indonesia is an implementation of disaster management mitigation model that is interesting to be socialized. Ability to utilize local wisdom in building the value of togetherness and wisdom in maintaining and preserving the environment became one of the keys to its success. Building a resilient community while maintaining local cultural values will become a force in building disaster mitigation management of volcano. People remain convinced that behind the disaster there will be a blessing that will be better for the future.

Based on the results of the study on the behavior of the community around Kelud and Merapi mountains, two important concepts were found in developing a disaster mitigation model based on local wisdom that is the compliance of the community in building a harmony with nature by maintaining the natural environment condition to stay sustainable and building the spirit of togetherness in emotional bond through ritual ceremonies. These two aspects become the basic capital in facing all the threats of volcanic disaster and illustrate the importance of local wisdom in building a society that has resilience in the face of eruption disaster.

The meaning of local wisdom needs to be studied and developed scientifically so that it can be understood by the community at large and become an important part to be conserved as an effort to build a community that is resilience to disaster. The action that can be done is to integrate local wisdom in education and training.

## Author details

Eko Hariyono[1] and Solaiman Liliasari[2]*

*Address all correspondence to: liliasari@upi.edu

1 Physics Department, Mathematics and Natural Science Faculty, State University of Surabaya, Surabaya, Indonesia

2 Science Education Program, School of Postgraduate Studies, Indonesia University of Education, Bandung, Indonesia

## References

[1] Djalante R. Research trends on natural hazards, disasters, risk reduction and climate change in Indonesia: A systematic literature review. Natural Hazards and Earth System Sciences Discussions. 2016;**342**. DOI: 10.5194/nhess-2016-342

[2] Guha-Sapir D, Vos F, Below R, with Ponserre S. Annual Disaster Statistical Review 2010: The Numbers and Trends. Brussels: CRED; 2011. Available from: http://www.cred.be/sites/default/files/ADSR_2010.pdf

[3] Mukhlis T, Syakur T, Dharma D, Anhorn J. School preparedness and training for geological hazard mitigation: An example from Indonesia. Disaster Management and Human Health Risk. 2017;**173**:113-119. DOI: 10.2495/DMAN170111

[4] Carter WN. Disaster Management: A Disaster Manager's Handbook. Mandaluyong City, Phil.: Asian Development Bank; 2008

[5] Wilkinson E, Lovell E, Carby B, Barclay J, Robertson RE. The dilemmas risk-sensitive development on a small volcanic island. Resources. 2016;**5**(21):1-20. DOI: 10.3390/resources5020021

[6] Christia M. Experiences of People Affected Merapi Eruption in 2010, A Qualitative Study Conducted in Krinjing Village Indonesia [Thesis]. University of Oslo; 2012

[7] Caldera J, Wirasinghe S. Analysis and classification of volcanic eruption. In: 10th International Conference of the International Institute for Infrastructure Resilience and Reconstruction (I3R2). West Lafayette, Indiana, USA: Purdue University; 2014. pp. 128-133

[8] Lavigne F, De Coster B, Juvin N, Flohic F, Gaillard JC, Texier P, et al. People's behaviour in the face of volcanic hazards: Perspectives from Javanese communities, Indonesia. Journal of Volcanology and Geothermal Research. 2008:273-287. DOI: 10.1016/j.jvolgeores.2007.12.013

[9] Jenkins SF, Barsotti S, Hincks TK, Neri A, Phillips JC, Sparks RSJ, Sheldrake T, Vougioukalakis G. Rapid emergency assessment of ash and gas hazard for future eruptions at Santorini Volcano, Greece. Journal of Applied Volcanology. 2015;**4**:16. DOI: 10.1186/s13617-015-0033-y

[10] Raga GB, Baumgardner D, Ulke AG, Torres Brizuela M, Kucienska B. The environmental impact of the Puyehue-Cordon Caulle 2011 volcanic eruption on Buenos Aires. Natural Hazards and Earth System Sciences. 2013:**13**;2319-2330. DOI: 10.5194nhess-13-2319-2013

[11] Frölicher TL, Joos F, Raible CC. Sensitivity of atmospheric $CO_2$ and climate to explosive volcanic eruptions. Biogeosciences. 2011;**8**:2317-2339. DOI: 10.5194/bg-8-2317-2011

[12] Frölicher TL, Joos F, Raible CC, Sarmiento JL. Atmospheric $CO_2$ response to volcanic eruptions: The role of ENSO, season, and variability. Global Biogeochemical Cycles. 2013;**27**:239-251. DOI: 10.1002/gbc.20028.2013

[13] Smyth R, Crowley QG, Hall R, Kinny PD, Hamilton PJ, Schmidt DN. A Toba-scale eruption in the Early Miocene: The Semilir Eruption, East Java, Indonesia. Lithos. 2011: **126**;198-211. DOI: 10.1016/j.lithos.2011.07.010

[14] Chesner CA. The Toba caldera complex. Quaternary International. 2011. DOI: 10.1016/j.quaint.2011.09.025

[15] Gertisser R, Self S. The great 1815 eruption of Tambora and future risks from large scale volcanism. Geology Toda. 2015;**31**:132-136

[16] Whelan F, Kelletat D. Submarine slides on volcanic islands—A source for mega-tsunamis in the quaternary. Process in Physical Geography. 2003;**27**:198-216

[17] Egorov Y. Tsunami wave generation by the eruption of underwater volcano. Natural Hazards and Earth System Sciences. 2007;**7**:65-69

[18] Kusky T. The Hazardous Earth Volcanoes Eruption and Other Volcanic Hazards. New York: Facts on File, Inc; 2008

[19] Dove MR. Perception of volcanic eruption as agent of change: On Merapi volcano, Central Java. Journal of Volcanology and Geothermal Research. 2008;**172**:329-337

[20] Iguchi M, Ishihara K, Surono HM. Learn from 2010 Eruption at Merapi and Sinabung Volcanoes in Indonesia. Vol. 54B. Kyoto Univ.: Annuals of Disaster Prevention Research Institute; 2011

[21] Subandi MA, Achmad T, Kurniati H, Febri R. Spirituality, gratitude, hope and post-traumatic growth among the survivors of the 2010 eruption of Mount Merapi in Java, Indonesia. Australasian Journal of Disaster and Trauma Studies. 2014:**18**(1)

[22] Tuswadi & Hayashi T. Disaster prevention education in Merapi volcano area primary schools: Focusing on student's perception and teacher's performance. Procedia Environmental Sciences. 2014;**20**:668-677

[23] Surono M, Jousset P, Pallister J, Boichu M, Buongiorno MF et al. The 2010 explosive eruption of Java's Merapi volcano—A '100-year' event. Journal of Volcanology and Geothermal Research, Elsevier. 2012:**241-242**;121-135

[24] Gunawan H, Surono BA, Kristianto PO, McCausland W, Pallister J, Iguchi M. Overview of the eruptions of Sinabung eruption, 2010 and 2013-present and details of the 2013 phreatomagmatic phase. Journal of Volcanology and Geothermal Research. 2017. DOI: 10.1016/j.jvolgeores.2017.08.005

[25] Muzambiq S, Syafriadi, Wijaksana BS, Rosaidi U. Characteristic of Sinabung volcano deformation of 2011-2012 estimated based on GPS data. Australian Journal of Basic and Applied Sciences. 2017:**11**(9);59-71

[26] Kadavi PR, Lee WJ, Wook-Lee C. Analysis of the pyroclastic flow deposits of mount Sinabung and Merapi using Landsat imagery and the artificial neural networks approach. Applied Sciences. 2017;**7**:935. DOI: 10.3390/app7090935

[27] Daniel J. CATDAT: Damaging Volcanoes Database 2010—The Year in Review. Available from: https://www.cedim.de/download/CATDAT_VOLC_Data_-_1st_Annual_Review_-_2010_-_James_Daniell_-_02.02.2011.pdf

[28] Donovan A, Eiser JR, Sparks RSJ. Scientists' views about lay perceptions of volcanic hazard and risk. Journal of Applied Volcanology. 2014;**3**:15. DOI: 10.1186/s 13617-014-0015-5

[29] Gonzáles-Mellado AO, De la Cruz-Reyna S. A simple semi-empirical approach to model thickness of ash-deposits for different eruption scenarios. Natural Hazards and Earth System Sciences. 2010;**10**:2241-2257. DOI: 10.5194/nhess-10-2241-2010

[30] King TA, Tarrant RAC. Children's knowledge, cognitions and emotions surrounding natural disasters: An investigation of year 5 students, Wellington, New Zealand. Australasian Journal of Disaster and Trauma Studies. 2013;**2013**:1

[31] Hariyono E, Liliasari S. The characteristics of volcanic eruption in Indonesia. In: Volcanoes. Tech Open Access; 2018. ISBN: 978-953-51-5610-9

[32] Cho SE, Won S, Kim S. Living in harmony with disaster: Exploring volcanic hazard vulnerability in Indonesia. Sustainability. 2016;**13**. DOI: 10.3390/su8090848

[33] Bachri S, Stotter J, Monreal M, Sartohadi J. The calamity of eruptions, or an eruption benefits? Mt. Bromo human-volcano system a case study of open risk perception. Natural Hazards and Earth System Sciences. 2015;**15**:277-290

[34] Wilson T, Kaye G, Stewart C, Cole J. Impacts of the 2006 eruption of Merapi volcano, Indonesia, on agriculture and infrastructure. GNS Science Report. 2007:**7**;69

[35] Latif DO, Rifa'i A, Suryolelono KB. Chemical characteristics of volcanic ash in Indonesia for soil stabilization: Morphology and mineral content. International Journal of GEOMATE. 2016;**11**:2606-2610

[36] Donovan K. Doing social volcanology: Exploring volcanic culture in Indonesia. Area. 2010;**42**(1):117-126. DOI: 10.1111/j.1475-4762.2009.00899.x

[37] PVMBG. Data Dasar Gunungapi Indonesia [Basic Data of Indonesia Volcanoes]. Ministry of Energy and Mineral Resource, Geology Department; 2010

[38] Kristiansen NI, Prata AJ, Stohl A, Carn SA. Stratospheric volcanic ash emissions from the 13 February 2014 Kelut eruption. Geophysical Research Letters. 2015;**42**:588-596. DOI: 10.1002/2014GL062307

[39] Schwendtner B, Papathoma-Köhle M, Glade T. Risk evolution: How can changes in the built environment influence the potential loss of natural hazards? Natural Hazards and Earth System Sciences. 2013:**13**;2195-2207. DOI: 10.5194/nhess-13-2195-2013

[40] Fatwa T, Asti MS, Wahyuni ST, Widodo H. The effectiveness of trauma healing methods to reduce post-traumatic stress disorder (PTSD) on teenage victims of Mount Merapi eruption. International Journal of Research Studies in Psychology. 2014;**3**:101-111

[41] Chadwick JP, Troll VR, Ginibre C, Morgan D, Gertisser R, Waight TD, Davidson JP. Carbonate assimilation at Merapi volcano, java, Indonesia: Insights from crystal isotope stratigraphy. Journal of Petrology. 2007;**48**:1793-1812

[42] Gertisser R, Charbonnier SJ, Keller J, Quidelluer X. The geological evolution of Merapi volcano, Central Java, Indonesia. Bulletin of Volcanology. 2012;**74**:1213-1233

[43] Indresputra F, Rahayu S, Widiyanto S. Effect of pyroclastic cloud from Merapi volcano to the survival of Uromycladium tepperianum on Falcataria moluccana in Yogyakarta, Indonesia. The 3rd International Conference on Sustainable Future for Human Security SUSTAIN 2012. Procedia Environmental Sciences. 2013:**17**;70-78

[44] Newhall CG, Bronto S, Alloway B, Banks NG, Bahar I, del Marmol MA, et al. 10,000 years of explosive eruptions of Merapi Volcano, Central Java: Archaeological and modern implications. Journal of Volcanology and Geothermal Research. 2000;**100**:9-50

[45] Troll VR, Deegan FM, Jolis EM, Budd DA, Dahren B, Schwarzkoff LM. Ancient oral tradition describes volcano earthquake interaction at Merapi volcano Indonesia. Swedish Society for Anthropology and Geography. 2015;**97**:137-166

[46] Gunawan H. The wisdom of the community on the southern slopes of Merapi, Sleman District – The special region of Yogyakarta. Sosio Informa. 2015:**1**(02)

[47] Fatkhan M. Kearifan lingkungan masyarakat lereng Gunung Merapi (Environmental wisdom community slope of Mount Merapi). Aplikasia. 2006;**VII**:107-121

[48] Setyawati S, Pramono H, Ashari A. Kecerdasan tradisional dalam mitigasi bencana erupsi pada masyarakat lereng Baratdaya Merapi (Traditional intelligence in eruption disaster mitigation on peoples of the south-western slopes of Merapi). SOCIA: Jurnal Ilmu-Ilmu Sosial. 2015;**12**(2):100-110

[49] Pardo N, Wilson H, Procter JN, Lattughi E, Black T. Bridging Maori indigenous knowledge and western geosciences to reduce social vulnerability in active volcanic regions. Journal of Applied Volcanology. 2015;**4**:5. DOI: 10.1186/s13617-014-0019-1

[50] Mungmachon MR. Knowledge and local wisdom: Community treasure. International Journal of Humanities and Social Science. 2012;**2**:174-181

[51] Jóhannesdóttir G, Gisladóttir G. People living under threat of volcanic hazard in southern Iceland: Vulnerability and risk perception. Natural Hazards and Earth System Sciences. 2010;**10**:407-420

[52] Maferetlhane OI. The role of indigenous knowledge in disaster risk reduction: A critical analysis [Mini Dissertation]. Master of Development and Management at the North-West University, Potchefstroom Campus. 2012

[53] Nazaruddin, M. Natural Hazard and Semiotic Changes on the Slope of Mt. Merapi, Indonesia [Master Thesis]. University of Tartu Faculty of Philosophy, Department of Semiotics; 2013

[54] Rist S, Guebas FD. Ethnoscience—A step toward the integration of scientific and indigenous forms of knowledge in the management of natural resource for the future. Environment, Development and Sustainability. 2006;**8**:467-493

[55] Arain F. Knowledge-based approach for sustainable disaster management: Empowering emergency response management team. Procedia Engineering. 2015;**11**:232-239

[56] Syahputra H. Role of local wisdom in acceleration of disaster risk reduction in Aceh (Kabupaten Simeulue case). In: 5th Annual International Workshop & Expo on Sumatra Tsunami Disaster & Recovery 2010. 2010

[57] Kelman I, Mather TA. Living with volcanoes: The sustainable livelihoods approach for volcano-related opportunities. Journal of Volcanology and Geothermal Research. 2008;**172**:189-198

[58] Texier-Teixeira P, Chouraqui F, Perrillat Coulomb A, Lavigne F, Cadag JR, Grancher D. Reducing volcanic risk on Fogo volcano, Cape Verde, through a participatory approach: Which outcome?. Natural Hazards and Earth System Sciences. 2014:**14**;2358-2374. DOI: 10.5194/nhess-14-2374-2014