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Character of community response to volcanic crises at Sinabung and Kelud volcanoes

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ABSTRACT

Volcano disaster mitigation is a priority in Indonesia's national development plan due to the large number of active volcanoes, high frequency of eruptions and dense population within volcanic hazards zones. As a consequence of these factors and the many decades of experience in mitigation of volcanic risk, Indonesia demonstrates that effective community response is critical to avoid disasters.

Understanding of hazards, risks and early-warning systems are the main factors in building an effective community response. The level of understanding of these factors is proportional to a community's independence in taking appropriate actions and is reflected in the community's preparedness. Further, the experience gained from responses to the eruptions of Sinabung and Kelud as well as from other Indonesian volcanoes shows that a local leader plays an important role in mobilizing a community. Such a leader utilizes knowledge of local culture (local wisdom) and an understanding of the community's character to encourage community members to participate and empower themselves. Sharing of information and the formulation of a disaster mitigation plan by government and community also results in a shared commitment to increase participation and community empowerment.

Indonesia uses four volcano alert levels to activate community mitigation plans. In order of increasing criticality, these are: Normal, Advisory (Waspada), Watch (Siaga) and Warning (Awas). Implementation of policies, strategies and actions are tied to each level. In addition, mandatory actions by certain stakeholders are required at certain alert levels. These mandatory actions increase the effectiveness of disaster mitigation by both government and community.

A comparison of the crisis responses of the Sinabung and Kelud communities is carried out here in order to better understand problems, learn lessons and improve the process of Indonesia's community mitigation policies. Local culture, the start time of community involvement (in normal versus crisis time), degree and level of government involvement, roles of local leaders, local perception of hazards, and political intervention are all factors that influence a community's response at the time of eruption. We stress that an understanding of the "*community character*," which includes a number of cultural, social and knowledge parameters is essential for effective crisis management. The responses of Sinabung and Kelud illustrate both the key role of community in disaster mitigation and the synergy that can result from close coordination and collaboration between government and community.

1. Introduction

Indonesia consists of 17,504 islands and 749 languages (Direktorat Jendral Otonomi Daerah, Ditjen OTDA, 2015) with a total of 1,919,440 sq. km area (Encyclopedia of the Nations, 2016). The nation has diverse cultures and characters of communities. According to Warren (1972), 'character of community' describes a population living in certain area, with shared traditions, values and social interactions.

In Indonesia, volcanoes provide both benefits and threats to communities living within hazard zones. Benefits include rich soils and cool climates for agriculture and tourism and fresh sand and rock resources for construction. Consequently, improving the capacity of communities in hazard zones not only reduces the risk of disaster, but also enables wise use of volcanic resources during dormant periods. Referring to

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the United Nations International Strategy for Disaster Reduction (ISDR, 2009), 'capacity' includes improvement in knowledge, skill, character and social management to maintain a sustainable livelihood. In the context of this paper, 'capacity building' means building the ability to cope with and respond to volcanic eruptions. According to Kelman and Mather (2008) living with both volcanic risks and benefits can be implemented through an improved understanding of volcanoes and managing the social conditions during both volcano crisis and non-crisis times. In disaster mitigation, there are three steps in such processes; before, during and after crises. Disaster management institutions and communities at-risk are involved in these steps.

A disaster is a serious disruption in the functioning of a community, which exceeds its capacity to cope within its own resources (Bradley et al., 2014). In more detail, the ISDR (2009) includes the human, economic and material losses as impacts of disaster. To avoid such loses, it is important for a community to understand the risks and potential impacts of disaster and to build capacity to cope with a crisis before it happens (O'Brien and Mileti, 1992; Mileti, 2010; Mileti et al., 2011a, 2011b). There are numerous examples of failures and successes in disaster management that have been analyzed by considering basic sociological concepts. In the general case, Paton et al. (2008) noted how the quality of relationships between parties is important for people to take action when faced with the consequences of volcanic hazards. Cronin et al. (2004) showed in more detail how differences in the perspectives between community members, scientists and emergency decision makers resulted in distrust during a volcanic crisis in Vanuatu. Best practices for development of community preparedness to anticipate volcano eruption have been widely discussed in previous work (e.g., Mei and Lavigne, 2012; Donovan and Oppenheimer, 2014; Andreastuti et al., 2017).

In this paper we explore changing responses to two contrasting eruptions in Indonesia. We present our empirical observations of the recent eruptions and consequent community responses at Kelud and Sinabung. We use our observations of the ensuing communication processes with local communities to consider the most important controls on building their capacity to cope. We also consider the role that Indonesia's volcano scientists have played in the mitigation of volcanic risk.

We use and modify the framework suggested by Tilling (2008) and find that a good understanding of the 'character' of a community contributes to improved communication and encourages participation in mitigation measures. The characteristics examined are culture, past experience with disaster, local capacity and vulnerability, as well as the availability of resources, sources of reliable and authoritative information, presence of local leaders, and community mitigation networks. Our knowledge of this character also promotes an understanding of the concept of risk, which involves both natural (physical) and human (behavioural) aspects (Eiser et al., 2012). In our experience, trust in officials and among community members as well as trust in a local leader is all important. Trust is built through consistency, confidence, ability and reliability and results in a shared understanding of hazard and risks between parties. By comparing two eruptions in which there were extremely different initial capacities within the local population as well as differing eruptions durations, we are able to understand some of the key drivers of a community's capacity to cope. Both eruptions occurred within the framework of the same disaster risk mitigation strategy.

1.1. Hazard mitigation in Indonesia

In Indonesia the mandate for volcano disaster risk mitigation is held by the Center for Volcanology and Geological Hazard Mitigation (CVGHM), Geological Agency, Ministry of Energy and Mineral Resources. To fulfill this role, CVGHM carries out research into volcanic processes and hazards, develops monitoring technology, and monitors volcanic unrest and issues alert notifications and warnings. In addition, CVGHM disseminates information to the public and to officials about volcano hazards and mitigation strategies.

Indonesia has 127 volcanoes that show some signs of activity (Fig. 1), comprising 77 type A volcanoes that experienced one or more eruptions since 1600 CE, 29 Type B volcanoes that last erupted before 1600 CE but have ongoing evidence of volcanic unrest, and 21 Type C volcanoes that have no record of historic eruption, but show fumaroles and/or sofatara activity. This classification is used to establish priorities for monitoring. To improve crisis management efforts, CVGHM collaborates with local government to disseminate information and undertake capacity improvement projects (Fig. 2). CVGHM has the mandate to provide information to local governments and to facilitate and support community-level capacity building. Local governments also have the mandate to facilitate and support community capacity building. Consequently, congruence of mitigation programs between CVGHM and local governments is needed to obtain optimum results.

CVGHM monitors the activity of 68 volcanoes of type A. Nine volcanoes of type A are not monitored, five of these are submarine and four are uninhabited volcano islands. The monitoring system is carried out through 12 regional centers (Fig. 3). Each center monitors two to seven volcanoes and communicates alerts. Indonesia's Volcano Alert Level consists of 4 stages, from the lowest to highest level of unrest and eruption these are: Normal, Waspada (Advisory), Siaga (Watch), and Awas (Warning) (Table 1). Each stage indicates a particular level of activity and each include a recommendation for community response. Hazard maps of Sinabung and Kelud are divided into three zones, from the highest to lowest: Hazard Zone III, Hazard Zone II, Hazard Zone I. Hazard Maps of Sinabung and Kelud are shown separately in subsequent sections (Fig. 6 and Fig. 7). Table 1 also lists lesson learned at Sinabung and Kelud communities with respect to awareness in each hazard zone.

The government of Indonesia has regulations and strategies concerning the transfer of hazard information, such as indications of increasing volcanic activity (Table 1), to communities. The government has also adopted strategies for the implementation of policies to strengthen communities' capacity to take appropriate response strategies. Law no. 24 (2007) of the Republic of Indonesia concerning Disaster Mitigation and one of its derivatives, the Law no. 21 (2008) of the Republic of Indonesia concerning Management of Disaster Mitigation contributes to capacity improvement. Elaboration of these laws is set forth in policy and action plans. These laws emphasize equity, partnership, and empowerment through local culture.

Improvement of community capacity is important to build community response in the time of crisis. Technical and non-technical parameters are involved. Technical parameters consist of education (including filling gaps in understanding and communication between scientists, government and community), early warning systems, and training in the field. Non-technical parameters include culture, the starting time of community improvement (normal or crisis), government involvement, the role of leaders, hazard perception, and political intervention. Non-technical parameters support and facilitate the implementation of technical parameters. We find that knowledge development through education can be more effective if it is supported by regulation and encouraged by local leaders. In addition, culturally sensitive approaches to communication of risk that recognize the character of local communities enhance their capacity and reduce their vulnerability.

Indonesia has a wide range of cultures, which results in differences in social behavior from community to community. In general, there is a strong linkage between members of each individual community. For examples, there are activities that emphasize inter-relationships between community members. These activities are carried by '*gotong royong*,' which means cooperation within a community's groups to achieve a positive outcome by consensus and collective deliberation (Effendi, 2013). Examples of these activities in communities near Merapi and Kelud volcanoes include helping to reconstruct other peoples' houses that were destroyed by eruption, and cleaning ash fall

Fig. 1. Distribution of Volcanoes in Indonesia.

deposits from schools, offices, and roads. During the Sinabung eruption, such cooperation was seen in the preparation of meals on the first 3 days of evacuation for people who stayed in other community's Jamhur (meeting halls). The gotong royong represents a culturally sensitive approach and has become an asset of community empowerment. Mileti and Fitzpatrick (1992), stated that risk communication and community response are also influenced by how other people accept and respond to information. Our observations show that relationships between community members will also contribute to an improvement in the community capacity to respond to hazard information.

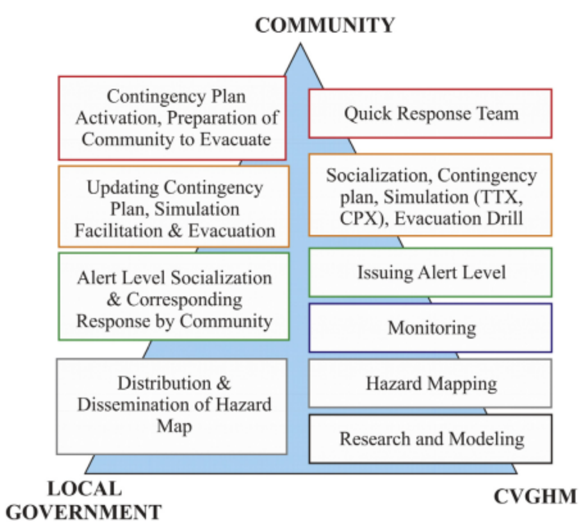

Fig. 2. Volcano Hazard Mitigation in Indonesia, showing relative roles of involvement by local government, CVGHM, and communities.

It is widely recognized that successful mitigation depends on the effectiveness of early warning systems and community responses (Saarinen, 1985; ADRC, 2000, ISDR, 2008) and communication strategies to deliver forecast perception (Doyle et al., 2014). According to the ISDR (2009), an "*early warning system is the set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss.*" The Indonesian strategy follows this definition in its early-warning alert system, as outlined above.

In our experience in management of past crises and disasters, we find that the most common problem that arises during a volcano crisis is a breakdown in communication between the source of information (scientists), decision makers (disaster management institutions) and the groups of potentially threatened people (communities). Similar results are documented by Haynes et al. (2008) and Cronin et al. (2004). Establishment of Indonesia's Law no. 24, 2007 has prompted a paradigm change in Indonesia from a focus on programs that respond to disasters to those that focus on preparedness. The many different cultures, languages, geographical settings, levels of knowledge, and sources of income are all factors that affect disaster management in Indonesia. Therefore, it is necessary to explore and learn the linkages of and

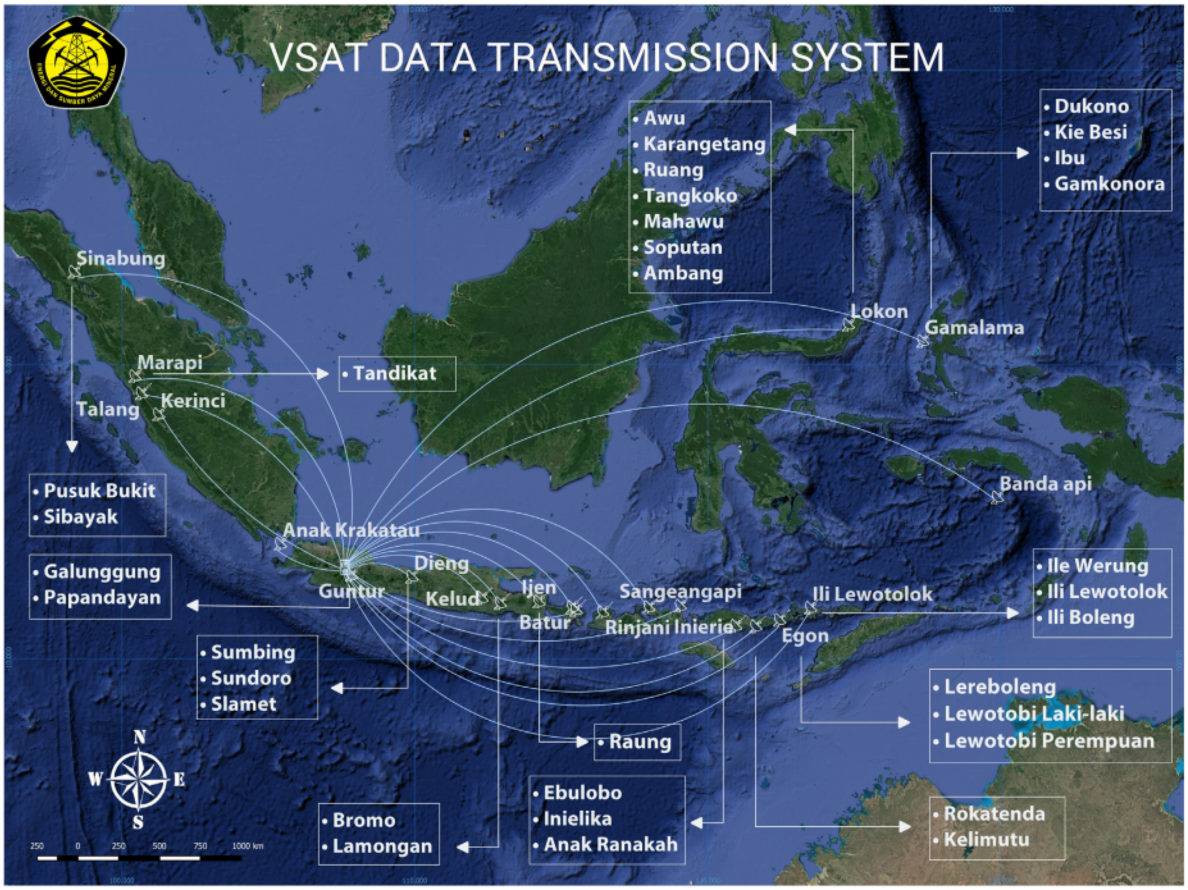

Fig. 3. Monitoring network of Indonesia volcanoes. Monitoring is managed through 12 regional centers shown by boxes. Each center monitors 2–7 volcanoes (as listed in the boxes; note that the volcano at the origin of each arrow is included in each center). Satellite dish symbols and curved lines indicate transmission of signals to CVGHM headquarters in Bandung's.

connections between society and culture before determining the best strategy to enhance communication and fill the gap between parties. Hiwasaki et al. (2014), proposed that selected local and indigenous knowledge be integrated in science and implemented in community risk reduction. As a part of culture, religion must also be considered in disaster mitigation (Chester, 2005; Andreastuti et al., 2017). The various aspects discussed above pinpoints the important role of community in disaster management. In Sinabung, most of people are Christian, therefore the role of priests as religious leaders become important. This is reflected by the role of religious leader in distribution of evacuees and managing their needs.

Tilling (2008) noted that monitoring data are scientifically valid for only short term forecasts of eruptive behavior. Such data are invaluable, but unless communities are prepared to receive and understand forecasts, alert levels, warnings and evacuation orders, disaster may still take place. Therefore, carrying out the basic hazard mitigation strategies outlined previously is especially important at reawakening volcanoes, where nearby communities are not accustomed to volcanic activity. A main issue in hazard mitigation is how to deliver results of monitoring in the form of alert levels to the community and how people interpret and take action according to this information.

In response to the reawakening of Sinabung volcano, government authorities have implemented strategies to improve the capacity of nearby communities through dissemination of information, formulation of contingency plans and risk mapping. Hazard information and dissemination of alert levels has been carried out through formal (scheduled by local government and CVGHM) and informal (unscheduled, face to face meetings with local people in the farming area, and by CVGHM) socialization. Hazard information is distributed through command posts and local government facilities. At Sinabung, the necessity for rapid forced capacity building resulted in less understanding and unfiltered delivery of information. Consequently, it became difficult for community members to determine the most important messages. This is a common problem with top-down information dissemination (Lestari et al., 2014). However, over time there has been an improvement in the capacity of communities and lesson learned are shown in Table 1.

1.2. Character of communities

1.2.1. Sinabung volcano

The reawakening of Sinabung Volcano, West Sumatra began on 27 August 2010 with phreatic/phreatomagmatic eruptions which continued into September of the same year. The volcano was then quiet until 15 September 2013 when eruptions began again and have continued to the present as summarized in other papers in this special issue. The eruption has had a major impact on disaster management in Indonesia. No eruptions of Sinabung before 2010 are known in the historic record back to 1600 CE. Dating of what appears to be the youngest pre-2010 pyroclastic deposit yields a ^{14}C age of approximately

Table 1
Alert levels for volcanic activity in Indonesia with linked community responses.

Level of volcanic activity	Indication	Community response	Lesson learned	
			Kelud	Sinabung
Normal level	Visual observations and instrumental records show normal fluctuations and no change of activity. Hazards in the form of poisonous gas may be present near vents, depending on the volcano's characteristic activity.	Communities in Hazard Zones (HZs) I and II may carry out daily activities. Communities in HZ III may carry out daily activities as long as they are in compliance with regulatory requirements from local government according to the technical recommendation of the Geological Agency, Ministry of Energy and Mineral Resources.	Community uses Early Warning System and resources in hazard zones to strengthen human resources, economy and society	Community uses resources in hazard zones to strengthen human resources, economy and society
Waspada level (advisory)	According to visual observations and instrumental records, there are indications of increasing volcanic activity.	Communities in HZ I and II may carry out their normal activities, but must keep alert. For communities in HZ III it is recommended that they do not to carry out daily activities in areas near summit craters or other vents.	Communities understand the value of coordination in mobilizing resources to anticipate eruption.	Communities carry out dissemination of knowledge to better understand hazard of Sinabung
Siaga level (watch)	According to visual observations and instrumental records, there are prominent indications of increasing volcanic activity. Eruptions may take place, but do not threaten settlements and/or activities of communities near the volcano.	Community in HZ I should improve their awareness and must not carry out activities along river valleys that originate at or near the volcano's summit. Communities in HZ II should start to prepare for evacuation and await an evacuation order from the local government according to the technical recommendation of the Geological Agency, Ministry of Energy and Mineral Resources. Communities in HZ III are not permitted to carry out daily activities and should prepare to evacuate.	Communities systematically capable to organize preparedness for independent evacuation.	Communities are better organized to evacuate independently.
Awas level (warning)	According to visual observations and instrumental records, there are significant indications of ongoing volcanic activity, with eruptions that potentially threaten settlements and or communities around the volcano.	Communities in HZ I, II, and III are to immediately to evacuate by the order of local government, according to technical recommendation from Geological Agency, Ministry of Energy and Mineral Resources.	Evacuation was carried out independently and with conscience in collaboration with important actors.	Independent evacuation can be done according to selected location by level according to degree of hazard and threatened area.

Fig. 4. The extent of exclusion zones during 2013–2015 activity, to south - southeast (7 km), to southeast-east (6 km), to north-northeast (4 km), and the rest is 3 km. Image base is from Google Earth.

1200 years BP (Hendrasto et al., 2012) and suggests a dormant interval of >800 years.

Since 2010, Sinabung has been at the highest alert level three additional times, in 2013, 2014 and 2015. And since 2 June 2015, the alert level of the volcano has remained at the highest level Awas (Warning).

The awakening of Sinabung provides lessons not only to volcanologists and decision makers, but also for communities. The prolonged crisis prompted sector-based disaster mitigation to be rapidly learned and adapted as conditions at the volcano changed. Sector-based mitigation was implemented because the volcano produced pyroclastic flows that impacted specific sectors of the volcano's flanks and these sectors have varied over the course of the eruption. Similar sector-based hazards and mitigation strategies were also used at Merapi volcano (Ratdomopurbo et al., 2013). During the 2010 VEI 4 eruption of Merapi, semi-circular exclusion zones were extended in sectors as the degree of eruption threat in those sectors increased and then these zones were contracted as the activity decreased (Surono et al., 2012; Pallister et al., 2013).

Fig. 4 shows the sectors used at Sinabung, in order of highest to lowest hazards and with distances of the exclusion zones: south - southeast (7 km), southeast-east (6 km), north-northeast (4 km), and other sectors (3 km). Differences in distance of exclusion zone from the summit depend on potential threat from the activity. For example, Fig. 5 illustrates how rapid dome growth and subsequent collapse produced pyroclastic flows that shifted from one sector (south) to another (southeast).

Because of the lack of previous eruptions, it was necessary for the people living in the area to rapidly learn about the types of hazards posed the volcano and how they could affect their individual communities. Two-way communication with the Sinabung communities has been carried out with CVGHM. In the Normal alert level, local leaders of Sinabung communities have frequently contacted CVGHM to arrange socialization and training to improve understanding of hazards and risks. Socialization was intensified during the increase in activity. Programs were carried out in villages within threatened areas and in the evacuation barracks. During the early stages of the crisis, we found that the communities who were in the process of capacity development were both curious and credulous of information provided. Common questions asked by community members included: Why is Sinabung erupting? How long will the activity continue? Why is my house in the hazard zone?

Individual institutions tended to provide information quickly without considering whether the information was part of their institution's mandate. At times, this caused public confusion due to unclear sources of authoritative information and due to misunderstanding. In some cases, the information was not understood by the information carrier, causing the meaning to be distorted and leading to bias and inconsistency. As an example, during the crisis many actors wanted to be involved and provide information and as a result, some information carriers did not understand the sequence of volcano alert levels and they provided incorrect information.

The frequent eruptions, characterized mainly by Merapi-type dome-collapse pyroclastic flows, associated ash fall and minor lahars have destroyed or severely damaged 10 villages and 2 hamlets and displaced 9323 people (as compiled through September 2016 in an evaluation report by CVGHM). These loses have taken place mainly within 5 km of the Sinabung summit. Direct fatalities associated with the eruption took place on 1 February 2014, when sixteen people ventured into the closed area. This tragedy and the overall unpleasent experience of the long-lived eruption and prolonged period of highest alert level (i.e., many months at the Awas level since June 2015) has stimulated the local communities and the institutions responsible for volcano monitoring and emergency management to become even more involved in hazard mitigation. As previously noted, before the reawakening, Sinabung had no monitoring system. Following the initial eruptions in 2010 and afterward, monitoring equipment has been installed and the volcano is now effectively monitored and information from the monitoring network is helping the scientists understand the character of the volcano and to provide better information to the public. At present, six seismic stations, four GPS stations, four tiltmeters, two CCTV web cams, three EDM stations, as well as mini-DOAS monitoring of SO_2, and a thermal camera are used to monitor the volcano, as described in other papers in this issue. Monitoring has been carried out continuously and information from monitoring is given in reports that accompany alert level notifications. These reports are delivered to National, Provincial and Local Disaster Management Agencies and to related stakeholders. The reports are provided in intervals that vary with alert level. During Level I (Normal) reports are issued monthly, at Level II (Advisory) they are issued every fortnight, at Level III (Watch) they are issued every day and at Level IV (Warning), reports are issued every 6 h.

During the Sinabung unrest, communities have been facing hazards in their daily lives. This condition encourages them to improve themselves by seeking information through the command or observatory posts. Socialization has also been carried out in threatened areas, scheduled by CVGHM or in response to requests from local leaders. The continuous activity of Sinabung also forced scientist to understand better the community as well as the volcano. Frequent encounters between community members, scientists and local government officials facilitated better communication and understanding of hazards and threats. New geological and hazard maps were created. Due to the progress of activity and changes in distribution of eruptive products, the hazard map of Sinabung was revised 3 times (Fig. 6). These maps were distributed and communicated to the communities. Over the extended period of the eruption, socialization and communication between stakeholders and communities and community leaders has been ongoing. The long

Fig. 5. Telephoto images of the summit area of Sinabung volcano, as viewed from the southwest. Rapid change of dome growth and direction of dome collapse led to adjustment of exclusion zones. Left image showed dome growth to the west of the central ridge, which resulted in dome collapse to the south. Right image shows dome growth to the east of the central ridge, resulting in collapse to the southeast.

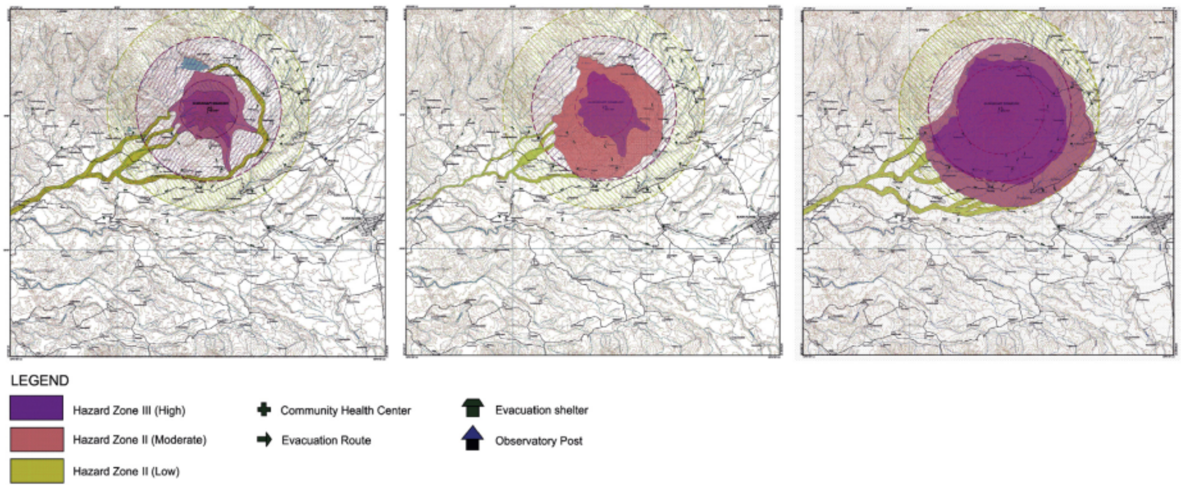

Fig. 6. Development of hazard maps of Sinabung according to activity. Fig. 5a (left) shows first version of hazard map of Sinabung, published in 2011. Fig. 5b (middle) shows a second version of hazard map after the beginning pyroclastic flows (2013). Fig. 5c shows a third version of the map after additional eruptions and a shift of collapses and pyroclastic flows to the southeast. Evacuation routes, evacuation shelters and the location of Observatory Post are indicated. Village names and some symbols are from the map base may be too small to be legible in this figure; however, the full-scale map is included as a supplementary electronic file (see Appendix).

lasting evacuation and forecast of a continuation for several more years (Wolpert et al., 2016) has resulted in the relocation of 1700 people and a high cost of emergency management.

1.2.2. Kelud volcano

Many historic eruptions of Kelud, with the notable exception of the passive lava dome eruption of 2007, are characterized by short durations, high explosivity and large volumes of tephra. Since 1000 CE, Kelud has had approximately 40 eruptions (Siebert et al., 2014). The most recent eruption before 2014 was the non-explosive VEI 1 2007 eruption that filled part of the crater with a lava dome. However, of the 10 eruptions since 1900 A.D, five were large VEI 4 eruptions. In 1919, a VEI 4 eruption and associated lahars produced when the crater-lake water was ejected killed an estimated 5000 people. Subsequent VEI 4 eruptions in 1919, 1951, 1966 and 1990 killed another 250 people. The last of these VEI 4 eruptions before 2014 was in 1990; this eruption killed > 30 people. Therefore, before and during the 2014 VEI 4 eruption, the hazards of Kelud were still very much in the public memory. Products of Kelud include: lava domes and flows, tephra falls, pyroclastic flows, volcanic ash and lahars. And as noted above, the explosivity of Kelud eruptions has ranged from VEI 1 to VEI 4, with effusive to explosive and phreatic-phreatomagmatic, vulcanian, sub-plinian and plinian eruption types. A hazard map of Kelud is shown in Fig. 7. The map is divided into 3 zones, from the highest to lowest: Hazard Zone III, II, and I.

Effective warning, mitigation and effective responses of communities near the volcano took place during the most recent eruption of Kelud on 13 February 2014. Steps of alert levels, training, table-top exercises (TTX), command post exercises (CPX) and evacuation drills, formulation and activation of contingency plans, and the early warning system all worked exceptionally well. Steps of procedures were defined and executed, communication and coordination between stakeholders, scientists and communities went well. There was also good communication between community members. People knew where to go during evacuations and they understood the procedures. Some people also managed to evacuate independently.

A total of 166,000 people managed to evacuate after the Awas (Warning) level was issued at 21:15 local time on 13 February 2014 (and before the first eruption began at 22:50 the same night). Even before the Awas warning was announced, a number of vulnerable people were evacuated earlier in the evening. In this situation, the local communities and the government have had a long-standing and mutual collaboration in dissemination of information. People actively participated in seeking information from the CVGHM observatory post; they understood the meaning of the activity and alerts and the information was effectively distributed within the communities at risk. The alert level was decreased from Warning to Watch on 21 February 2014 and most of the evacuees were returned home. Some people were still living at evacuation barracks due to heavy damage of their houses, therefore reconstruction has been required.

1.2.3. Building the character of communities

Lesson learned from various communities around volcanoes in Indonesia, including Sinabung and Kelud, show that "community character" greatly contributed to the improvement of community capacity, which takes into account culture, past experience with disaster, local capacity and vulnerability, as well as the availability of resources, sources of reliable and authoritative information, presence of local leaders, and community mitigation networks (Fig. 8).

Past experience of disasters during Kelud eruptions is reflected in terminology related to hazards used by communities. Hot mud flows or 'hot lahars' is a terminology derived from Kelud eruptions and imply the products of phreatic eruptions. This terminology is well known in communities and means that they have experienced and understand the hazard in their lives. They also used the term 'cold lahars' for rain-triggered mud flows to differentiate them from 'hot lahars'. Knowledge of these terminologies and their impacts also indicates understanding of their vulnerability and how to mitigate risks.

Communication of hazards and risks at Kelud has been carried out by handy talky (portable radio) and community radios. Information is obtained from the observatory post and delivered to communities in this manner. At least 13 community radio stations exist around Kelud Volcano, in Blitar (southern flank), Kediri (northwestern flank) and Malang (northern flank) Regencies. Nine of these are implemented with handy talky. Information shared to the public using these radio systems includes condition of the volcano, change of alert level, and mitigation recommendations as relayed from official sources. This information is delivered in informal and simple language. The hazard information is managed by community disaster preparedness teams that have emerged during the capacity-building process. The interesting point during communication is that the 'reporters' greet personally the

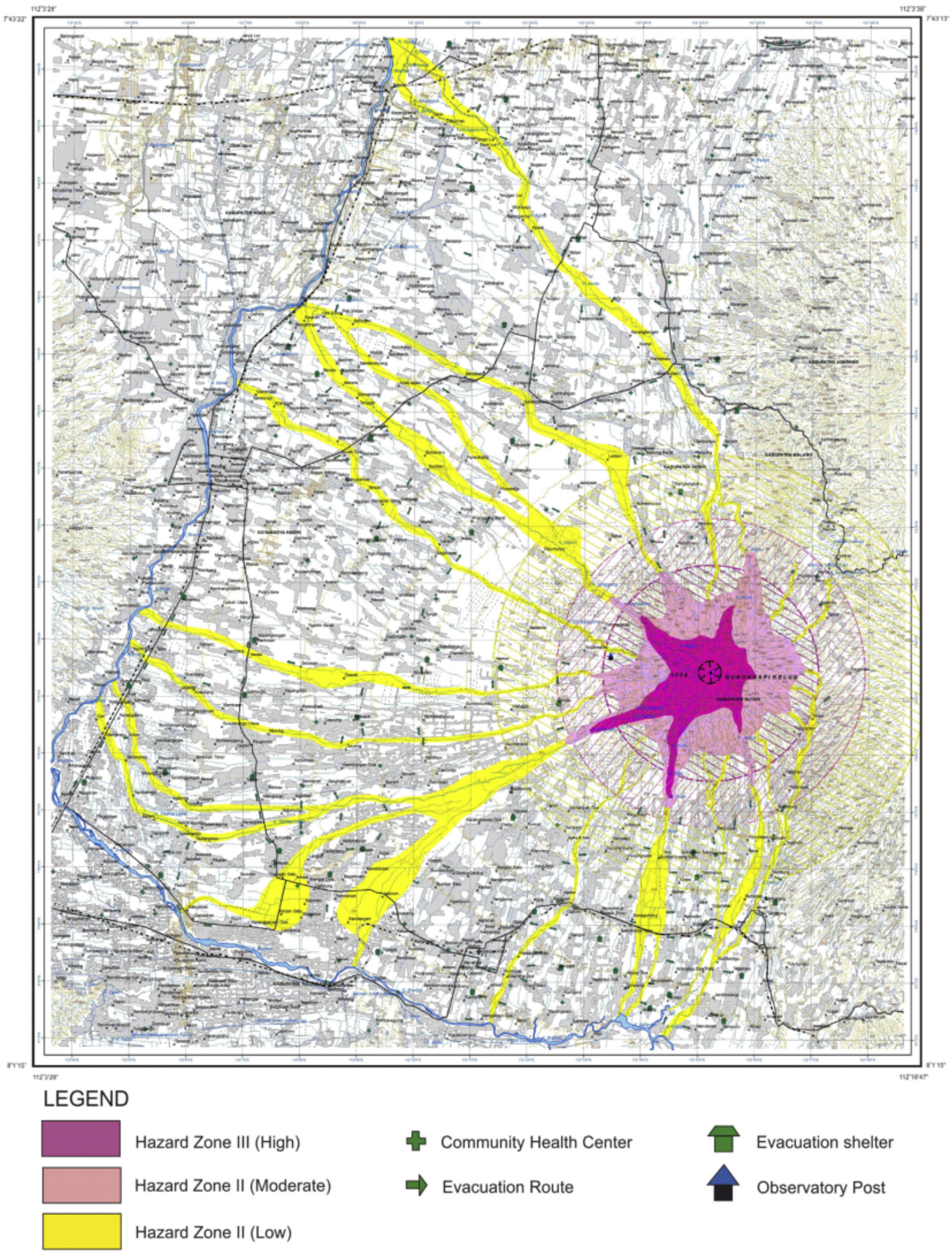

Fig. 7. Hazard Map of Kelud showing three hazard zones by color from the highest to lowest: Hazard Zone III, II and I and separated by dashed boundary lines at different radii. Solid colored polygons separately show areas subject to hazards from explosions and pyroclastic flows (in bright purple and pink) and from lahars (in yellow). Note that these generalized hazard maps were used as the basis for sector-based evacuation/exclusion zones as the eruption evolved, similar to those at Sinabung shown in Fig. 4. Evacuation routes, Districts, Evacuation Shelters and location of Observatory Post are also indicated. Areas in gray are populated. Village names and some symbols are from the map base and may be too small to be legible in this figure; however, the full-scale map is available as a supplementary electronic file (see Appendix).

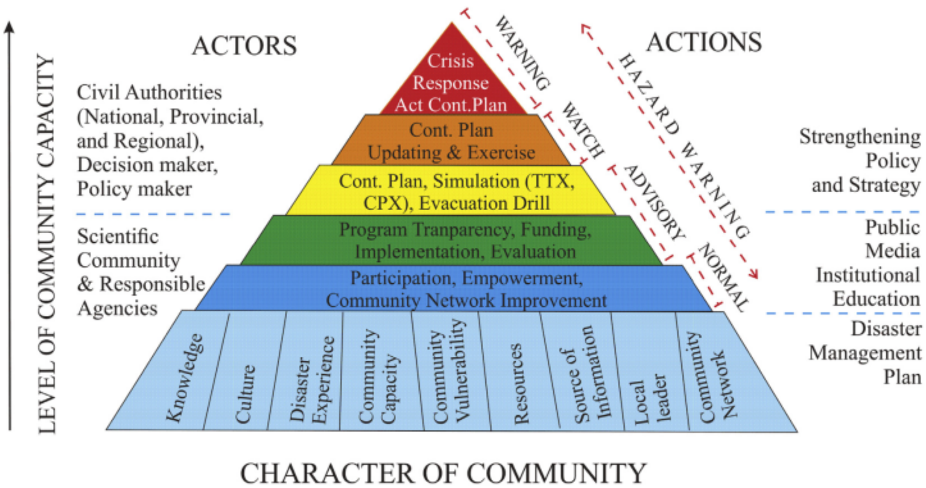

Fig. 8. Development of community preparedness through culture, capacity improvement and community empowerment. This figure illustrates how the level of community capacity ideally increases through contributions of a variety of community factors, shown at the base of the triangle, and increases upward through factors such as participation, implementation, simulation, planning and table-top and command-post exercises (TTX and CPX), and culminating with an effective crisis response and activation of a contingency plan ("Act Cont. Plan"). Principal actors are listed on the left and outcomes are listed on the right. The linkage between community and official actions are linked to alert levels and hazard warnings as shown by the red dashed lines.

listeners during radio broadcast. Therefore, they attract public interest and emotionally bind the listeners.

At Sinabung, the effort of dissemination of information through radio streaming took place during the end of 2013 during the increase of alert level to Warning. However, this activity could not be continued due to the prolonged crises time. People involved in this activity have other responsibilities related to disaster management. Crisis condition of Sinabung also prompted community members to provide information to the observatory post, such as sending photographs of visual observations. Further, in the mid-year of 2016, there was a change of the manager of the regional disaster management agency (BPBD) of Karo Regency. This also affected the implementation of policy and the manner of communication with stakeholders. The new manager visited CVGHM and discussed the strategy of hazard mitigation and obtained information related to Sinabung and other geological hazards.

1.2.4. Lessons learned from Sinabung

In the initially low-mitigation-capacity situation that existed in the communities of the Sinabung area during the early stages of the eruption, local government and related stakeholders paid less attention and communicated less with the communities at risk due to political considerations. Personal and group interests were sometimes emphasized over community interests. This condition was due to a low level of risk perception, less understanding of the hazard and less involvement of both formal and local leaders in hazard mitigation. A lesson learned is that in areas with more disaster experience, leaders show a commitment to communicate, share mitigation program, support disaster mitigation policy and maintain involvement in community activities.

Communities such as that of Sinabung that are in the process of capacity development typically need confirmation of information, and they question the same topic repeatedly. This reflects an unsure understanding of the condition, which should be anticipated. In this situation, we have found that if those responsible for hazard mitigation organize and coordinate quickly, such that they speak with a single voice, and if they treat the public curiosity and incredulity with respect, then building mitigation capacity can be accomplished. This strategy corresponds with IAVCEI Guidelines (Bretton et al., 2016).

Many factors contributed to capacity-building during the Sinabung eruption. At the beginning of the surprise 2010 eruption, lack of an instrumental monitoring system, lack of historical eruption data and lack of local public experience with eruptions led to widespread fear in the nearby communities. In 2013, when the volcano began erupting again, a seismic monitoring network and local observatory had been established by CVGHM, but there was still considerable fear among members of the public. In part, this fear can be related to the "100-year" eruption of Merapi on 5 November 2010, which destroyed a number of communities and was widely covered in the national and international media (Surono et al., 2012). In response to the fear and some continued mixed messages from institutions and the media, a strong socialization program was instituted, which focused on hazard and risk communication between stakeholders and communities and on establishing roles for local community leaders. This socialization program has continued and it has improved community preparedness and capacity to respond to the changing conditions brought about by the eruption. Most recently, since June 2015 the continued dome growth and collapse has resulted in pyroclastic flows that have affected an increasingly large area (Nakada, et al., Gunawan et al., Pallister et al., this issue). Consequently, the Alert has remained at the highest level (Awas) and a number of villages have had to be relocated. The socialization program played a key role in enabling the communities involved to respond to this considerable disruption. In addition, the socialization program has contributed in a substantial way to the limited loss of life during the eruption.

Disaster is an interesting topic; therefore it attracts people to become involved even though mitigation is not their area of expertise. People tend to distribute and comment or interpret data without considering the full situation. In the case of Sinabung, arguments and comments through social media, and initially without support of data, contributed to confusion and dangerous mixed messages; although in the end, the social media have enriched understanding of community and public character, including communication between mandatory institutions, stakeholders and communities.

In the case of Sinabung, relocation is a sensitive issue. It involves culture (attachment to ancestral land, involvement of local leaders), economy (land ownership, livelihood), potential for additional disaster in a relocation area, spatial planning, social facilities, social conflict (integration between existing residents and evacuees), involvement of community in defining relocation areas and infrastructure (Sagala, 2014). Therefore, there has been much information related to relocation and evacuation in the social media about Sinabung. Mostly external scientists and 'local celebrities' were involved in these discussions. Institutions with responsibility in disaster mitigation, such as CVGHM are frequently mentioned. The social media discussions can mislead and twist important messages. In this case, CVGHM has issued statements, which explain the development of Sinabung activity and its recommendations to rectify the problem.

In the early repose time at Sinabung (2011, 2012), local leaders invited CVGHM to give socialization and training to young communities. At the beginning and during the crises (2010, 2013-present), local leaders also invited CVGHM to give socialization programs. In 2013, under the coordination of Badan Nasional Penanggulangan Bencana (BNPB, National Disaster Management Agency), Badan Penanggulangan Bencana Daerah (BPBD, the regional disaster management agency), and CVGHM, local government and related stakeholders formulated a contingency plan for the Karo Regency. In 2015, a socialization program for high school students around Sinabung was carried out and socialization has been done frequently based on requests from local leaders and or local governments. Further, in 2015, village leaders around Sinabung were involved in identification of risk and capacity to support the creation of a risk map (Risk Map of Sinabung, unpublished report, 2015), in collaboration with several intitutions (CVGHM and universities). The progress in education of the Sinabung community is indicated by the results of this analysis. The risk analyses show that out of 34 villages (not including 10 villages in evacuation/relocation areas), 18 villages (53%) have moderate preparedness indices and the rest of villages have low preparedness indices (Table 2).

1.2.5. Lesson learned from Kelud

Capacity improvement of Kelud communities has been carried out extensively following the 2007 dome-forming eruption. CVGHM along with BNPB, local government and BPBD carried out such activities. A community-based disaster mitigation organization was established, Jangkar Kelud (Jangkane Kawula Redi Kelud-The Hope of Kelud Community), which collaborates with Nature Lover Community (KAPPALA) and Center for Disaster Management Study of Pembangunan National University.

Regularly, CVGHM has arranged preparedness activities, including identification of hazard and risk, distribution of hazard maps and implementation of plans and education programs in collaboration with BPBD and Jangkar Kelud. This important start to improve capacity of institutions and communities around Kelud was designed to establish synergy between community and government regarding who will be involved in the activity, through formal and informal activities. Meetings included discussions that led to the distribution of tasks, planning and conducting preparedness programs and establishment of teams to work in each regency.

CVGHM along with local government and BPBD have arranged institutional capacity improvements through socialization of volcanic hazard and risk, and the formulation and updating of contingency plans. Capacity improvement has been carried out both at the institutional and community level. CVGHM staff has also mentored school students and members of the communities in hazard zones in understanding hazards and building mitigation capacity. Social organizations have assisted in preparation of risk maps, formulation and updating of contingency plans at village levels, and capacity improvement of school students.

Table 2
Capacity indices of Sinabung communities in the Karo Regency.

District	Village	Index	Explanation
Tiganderket	Tiganderket	0.64	Moderate
Tiganderket	Susuk	0.60	Moderate
Tiganderket	Gunung Merlawan	0.53	Moderate
Tiganderket	Tanjung Merawa	0.43	Moderate
Tiganderket	Kuta Mbaru	0.34	Moderate
Tiganderket	Perbaji	0.33	Low
Tiganderket	Mardinding	0.32	Low
Tiganderket	Temburun	0.27	Low
Tiganderket	Suka Tendel	0.26	Low
Tiganderket	Jandi Meriah	0.18	Low
Tiga Binanga	Pertumbuken	0.46	Moderate
Tiga Binanga	Bunga Baru	0.11	Low
Simpang Empat	Beganding	0.34	Moderate
Simpang Empat	Serumbia	0.34	Moderate
Simpang Empat	Jeraya	0.27	Low
Simpang Empat	Kuta Tengah	0.27	Low
Simpang Empat	Torong	0.12	Low
Payung	Selandi	0.39	Moderate
Payung	Rimokayu	0.35	Moderate
Payung	Payung	0.30	Low
Payung	Ujung Payung	0.22	Low
Payung	Cimbang	0.09	Low
Namanteran	Gungpinto	0.66	Moderate
Namanteran	Kebayaken	0.48	Moderate
Namanteran	Ndeskati	0.45	Moderate
Namanteran	Naman	0.44	Moderate
Namanteran	Sigarang-garang	0.42	Moderate
Namanteran	Sukanalu	0.42	Moderate
Namanteran	Sukandebi	0.41	Moderate
Namanteran	Kutambelin	0.41	Moderate
Namanteran	Kota Gugung	0.31	Low
Namanteran	Kutarayat	0.31	Low
Namanteran	Sukatepu	0.25	Low
Merdeka	Deram	0.22	Low

Indices ≤0.33 are considered low; those >0.33 and ≤0.67 are considered moderate; those >0.66 are considered high.

2. Discussion and conclusions

Bird et al. (2011) denote that perspective and behavior of communities from different areas result in different responses. This is well represented by the responses of the Sinabung and Kelud communities. In Indonesia, the quality and intensity of social networking is the basis for community-based preparedness. This networking is encouraged and supported by the scientific community and responsible agencies for disaster mitigation. Community preparedness works best when the local culture is considered in all activities. Arnold (2007) suggested that community networks change the cultural, social, economic and emotional frame to give rise to a desire to respond. This condition is expected to improve communication and strengthen the character of communities. It is also helpful to identify potentially local leaders among community members. The establishment of community radio stations led by local leaders around Kelud is an example. Activities carried out by these communities reflect independent capacity improvement where communities are able to empower themselves and manage risks. It also shows the value of local leaders, good quality of relationships and community mitigation networks (Fig. 8.).

Fig. 8 shows the process of capacity building through culture as used in Indonesia. There are 4 main parameters that contribute the process: building the character of community leaders and establishing roles of community leaders, exploring culture values, and encouraging community self-reliance. The main point of the process is developing community leaders, who through local wisdom encourage individual community members to participate in disaster mitigation. In this way, communities develop preparedness and resilience. Social networking among community members, such as takes place in 'gotong royong,' is formed naturally by the local culture. According to Kalaycioğlu et al. (2006), social network mechanisms also play a role in decreasing the effect of disaster and in the way each individual anticipates the potential for disaster.

Social interaction also helps community members to explore their internal capacity, understand their potency and benefit from these qualities. In the case of Sinabung, social interaction through culture helps us understand the problem of evacuation management. At Sinabung, meals for evacuees are prepared by jamhur community hosts, and after several days, according to their culture and custom, the evacuees self-organize and take turns in fulfilling this and other community needs. However, at Sinabung, this custom was disturbed by the involvement of volunteers from inside and outside the country. The implementation of emergency procedures without considering local wisdom and culture has been problematic and the customary good practice ceased in certain evacuation barracks. This condition also affects the character of the evacuees, as they could not actively participate in the activities and they become dependent on the outside volunteers.

A lesson to us is that in culturally sensitive activities, a good understanding of the local culture is necessary. Otherwise there will be cultural degradation, which affects negatively the community response. It is important to use indigenous knowledge to improve community capacity. Accordingly, the strong cultural identity of the Sinabung people can be used to empower the community. A good example for the use of culture to strengthen community capacity is from Simeulue Island in Sumatera (Meyers and Watson, 2008). In Simeulue Island, people use traditional communication. Experience from an earthquake generated tsunami in 1907, which took high casualties, provided a good lesson to avoid the hazard. Besides understanding of the story as handed down from past generations, the community used the word 'smong' to describe tsunami and they know what to do in case of another tsunami. The word is from 'ni semongan' from the local language, which means splashing water.

In disseminating information, CVGHM carries out socialization intensively in both formal and informal meetings with the public. The methods used were designed to help to understand common problems faced by the local communities. During the Sinabung crisis, the common CVGHM process was to understand the hazard, and to expect people to seek information and ask directly for information from the observatory post. But in this case, strong arguments have taken place, and we have found that informal conversations are more effective and help to build trusting relationships. This condition reflects an acquaintance relationship and equity position. As noted by Haynes et al. (2008) the most trusted sources of volcanic information for the Montserrat community in West Indies are friends and relatives. As at Montserrat, trusting relationships and communication involving friends and relatives has been important in delivering volcanic hazard information during crises in Indonesia.

At Sinabung, there was a great demand for detailed technical information from the generally well-educated public. Consequently technical information was directly shared with an emergency information system that could be accessed by the public. The definition of technical terms, such as types of volcanic earthquakes, the basis for hazard maps and hazard zones became common questions. In summary, there were more detailed and persistent technical questions than CVGHM normally encounters at volcanoes where eruptions are common and socialization programs have long been in place.

Preparedness of volcano disaster mitigation has been carried out in Indonesia through issuing alert levels, formulation of policies and strategies and implementation of action plans. The involvement of disaster mitigation institutions is also organized according to their mandates. At the Normal Alert Level, a Disaster Management Plan is formulated. The plan includes strengthening policy and strategy, adoption of an information system and early warning system, and steps to implement the plan during a crisis. Table 3 displays the stages of policy, strategy, and action that need to be carried out according to increasing alert levels. All these steps take into account culture and resources, in addition to technical factors. The table also shows development of policies, strategies and action plans from the lowest alert level (Normal) to the highest level (Warning).

During a crisis, it is important to strengthen the information that contributes to the issuance of an alert level. We have concluded that development of eruption scenarios and related hazard is the right choice. This scenario approach is routinely implemented during volcanic crisis in Indonesia. Sector-based mitigation is applied to anticipate eruptions that produce pyroclastic flows, with hazard zones in sectors according to the direction of flows. Hazard mitigation measures such as evacuations affect the socio-economy of people living in the area. Therefore, in areas of high population around volcanoes such as Sinabung or Merapi, sector-based mitigation for dome-collapse type eruptions is used to minimize the extent of impacts on peoples' livelihoods. And accordingly, institutions with responsibility for disaster mitigation prioritize and focus their activities in threatened sectors. This strategy has been implemented at volcanoes which poses pyroclastic flow hazard and has proven effective and

Table 3
Preparedness of disaster management institutions and communities during each volcano alert level.

Alert level	Policy	Strategy	Actors	Action	Action by community
Warning (Awas)	Implementation of Disaster Mitigation System	Strengthening communication and coordination	Civil authorities (national, provincial and regional), decision makers, policy makers	1. Activation of contingency plan 2. Provide continuous and updated information 3. Share information	Use information to interpret and take action
Watch (Siaga)	Strengthening hazard information and early warning system	1. Development of information system 2. Checking of early warning system	Civil authorities (national, provincial and regional), decision makers, policy makers	1. Prepare to activate contingency plan 2. Contingency plan updating & exercises	Carry out updating of data in contingency plan and conduct exercises
Advisory (Waspada)	Strengthening policy and strategy	1. Improvement of collaboration among disaster mitigation institutions 2. Strengthening dissemination of information and early warning systems	Civil authorities (national, provincial and regional), decision makers, policy makers	1. Formulation of contingency and evacuation plans, 2. Formulation of simulation (TTX, CPX), and evacuation drill	Conduct exercise/simulation/evacuation drill
Normal	Formulation of disaster management plan	1. Transparency of programs, funding, implementation, evaluation 2. Public, media, institutional education 3. Explore culture and local resources 4. Utilize local resources 5. Research, mapping	Scientific community & responsible agencies	1. Building good communication between government and media 2. Encourage capacity improvement and community empowerment 3. Encourage community participation to enable understanding of hazard and disaster information 4. Build information and knowledge management systems 5. Develop database 6. Formulate evacuation model	1. Build good communication among community members, and between communities and government 2. Understand hazard and disaster information and actively participate in capacity improvement 3. Be involved in building information and knowledge management systems

Table 4
Comparison of community capacity of Sinabung and Kelud.

Parameter	Kelud	Impact	Sinabung	Impact
Knowledge	Good knowledge of community living in the highest risk zone.	1. Trust among community members and in scientists 2. Community members seek solutions with information provided	Uneven knowledge of community living in hazard zone.	1. Trust in community members; mistrust of scientists 2. Community members seek confirmation of information provided
Disaster experience, lessons learned	1. Regular experience from where people live and as volunteers in other volcanic crises (e.g. Merapi) 2. Experience in disaster management organizations	Understanding the character, threats and risks posed by the volcano	1. Lack of experience (beginning of activity) to continuous experience (later inactivity) 2. Lack of experience as volunteers involved in disaster management organizations	Questioning volcanic activity and effectiveness of response actions
Political intervention	1. Less political intervention, 2. Less influenced by political motivations due to equality between public and stakeholder.	Capable of encouraging and mobilizing community to respond at the time of disaster	1. Political intervention dominates. 2. Political motivations take a lead, small portion of public compared to stakeholders play a role	Decreasing motivation to become involved in disaster mitigation
Communication among community members	1. Good communication among and within communities 2. Planned and coordinated community	Builds internal and external community networks	1. Less coordination; communication carried out based on insufficient knowledge 2. Less planned and less coordinated community	Ineffective communication, inappropriate action due to misleading information
Coordination	1. Good coordination, Jangkar Kelud informally acts as a coordinator of standby team, village disaster preparedness team, and external community team.	Similar hazard perception is obtained	1. Lack of coordination, community places itself as an object. In the beginning acting as a subject, then gradually changing to be an object. Condition is possibly beyond people's endurance to cope with the disaster	The capability to anticipate disaster is lower than the progress of disaster
Mandate	1. Supported by stakeholders which evolved gradually 2. Stakeholders begin involvement in normal conditions, do not wait to start in the time of crisis 3. Stakeholder is willing to help. Regional disaster management agency has responsibility to take part	Good communication and coordination facilitate effective improvement of capacity and networking	1. Intervention of stakeholders 2. Stakeholders compete to be involved 3. Attention of local government is insufficient, therefore responsibility taken by provincial disaster management agency	Ineffective communication and coordination, influence disaster mitigation process
Establishment of Regional Disaster Management Agency (RDMA)	Malang Regency (September 2011) Blitar Regency (January 2012) Kediri Regency (February 2015)	The earlier establishment of RDMA, the more effective is the disaster management processes	Karo Regency (January 2014)	The later establishment of RDMA resulted in longer delay to have effective disaster management processes

efficient. However, this requires well prepared communities and government institutions and good communication between both parties.

Our experience shows that to be effective, local communities need to participate in the formulation of disaster mitigation plans. As previously noted, incorporating culture and local resources and implementation through education are best practices to obtain effective results. Paton et al. (2008), also confirms that effective education programs are enhanced by social interaction among community members.

In a hazard mitigation education program, it is important to emphasize the understanding of the early-warning system and evacuation model for the area where the community is located. This is necessary because community members need to know the process and procedure of evacuation and the specific actions they are to take. Communities around Kelud volcano are recognized for their effective response during the eruption of Kelud on 13 February 2014. This is because they understand well the contingency plan and risk maps of their areas (Andreastuti et al., 2017).

The process of capacity improvement is shown by comparing the responses of the communities of Sinabung and Kelud, as shown in Table 3 and Table 4. For each parameter, the impact is noted. Response of Sinabung and Kelud communities is compared for 5 parameters; knowledge, disaster experience, lessons learned, coordination, communication, mandate and establishment of a Regional Disaster Management Agency.

In general, Sinabung communities scored lower in: knowledge and disaster experience, coordination and communication in the ongoing crisis management, development of community leaders, trust in government scientists, and in understanding of risk. The absence of a Regional Disaster Management Agency until 2014 also contributed to problems in communication with the public. An important fact learned from the Sinabung crisis is the difficulty that resulted because both institutions and communities were forced to respond during the eruption without sufficient knowledge, policy, strategy, action plans, and facilities in place. Consequently, interagency planning for unanticipated eruptions is recommended.

In the case of Kelud, synergy and trust already existed between the government agencies and the community. The local communities have been involved and have participated in disaster management plans since 2007. Capacity-building by institutions and communities was already underway during the Normal alert level, therefore it increased as a gradual process as the volcanic unrest escalated. Communication and coordination were increased during the activities. As mentioned in previous sections, a disaster mitigation plan, contingency plan, simulation, and evacuation drill had been prepared by both government institutions and the community. Even though the establishment of Regional Disaster Management Agency of Kediri only took place after the eruption, because of participation and capacity of the community and support of the local government, people managed to respond appropriately and effectively during the 2014 crisis.

The Sinabung and Kelud communities have very different cultures. As an example, Sinabung communities have jamhurs where people visit or stay during certain occasions, such as evacuations. In contrast, Kelud communities don't have this culture. However, they have strong community-bonding to help other people, such as the gotong royong activities mentioned in a previous section. Perhaps, most importantly, the communities of Sinabung had less volcanic hazard experience compared to Kelud. In the case of evacuation, they have learned to evacuate independently according to directives from either religious or cultural leaders.

To improve volcano risk mitigation, representatives of communities, local leaders and formal leaders from several volcanoes (Merapi, Kelud, Semeru, Sinabung, and Egon) participated in a workshop during the Cities on Volcanoes 8 meeting in Yogyakarta in 2014. The aim of this workshop was to understand the needs of the various communities and to learn from previous responses. From the formal leaders, we learned also what they expect from CVGHM to mitigate the hazard and risk, and to share programs and activities.

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Appendix A. Supplementary data

High-resolution digital versions of the hazard maps presented in reduced format in this paper as Figs. 6 and 7 are available from the journal as supplementary electronic files. Supplementary data associated with this article can be found in the online version, at http://dx.doi.org/10.1016/j.jvolgeores.2017.01.022.

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