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Research paper

People's behaviour in the face of volcanic hazards: Perspectives from Javanese communities, Indonesia

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Abstract

This paper is concerned with the way in which the Indonesian people living on the slopes or near active volcanoes behave in the face of volcanic threats. It explores the role of three factors in the shaping of this behaviour, e.g. risk perception, cultural beliefs and socio-economic constraints. The paper is mainly based on field data collected during the last 5 years on four volcanoes in Central Java, namely Sumbing, Sindoro, Dieng, and Merapi.

The common assumption that hazard knowledge, risk perception and people's behaviour are closely related and conditional on volcanic activity is debatable in the Indonesian context. Factors that play a role in hazard knowledge—e.g. basic knowledge of volcanic processes, personal experience of volcanic crisis, time lapsed since the last volcanic eruption, etc.—differ from those that influence risk perception. Indeed, local people often underestimate the scientifically or statistically estimated risk. This poor risk perception is characterized by an approximate personal representation of the volcanic processes, an excess of trust in concrete countermeasures, the presence of a physical-visual obstructions, or cultural beliefs related to former eruptions.

In addition, the commonly-acknowledged factors that influence hazard knowledge and/or risk perception may be at odds with the non hazard-related factors that prompt or force people to live in or to exploit areas at risk. These factors may be either socio-cultural—e.g., attachment to place, cultural beliefs, etc.—or social and socio-economical —e.g., standard of living, strength of people's livelihoods, well-being. These factors are fundamental in explaining the short-term behaviour in the face of a developing threat during a volcanic crisis.

Keywords: volcano; risk perception; representation; Indonesia; legends

1. Introduction

The slopes of Indonesia's 130 active volcanoes have been densely populated for thousands of years. Frequent eruptions cause a heavy toll among local communities. Between January 1900 and August 2002, the EMDAT database of the Centre for Research on Epidemiology of Disasters (CRED) listed 39 disasters associated with volcanic eruptions that each killed at least more than ten people, hindered the life of more than 100 individuals, or required international aid (Centre for Research on Epidemiology of Disasters, 2006). These events killed almost 18,000 people. Millions of other Indonesians were directly or indirectly affected by volcanic eruptions. These disasters have long been considered solely from the angle of volcanic hazards through the disciplines of geophysics and volcanology. However, the last decades have seen a growing interest in the human dimension of disaster and people's

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behaviour in the face of volcanic hazards (Chester, 1993). This article particularly explores the role of three factors in shaping of people's behaviour in the face of volcanic threats. These factors are both hazard-related and non-hazard related and include risk perception, cultural beliefs and socio-economic constraints.

Risk perception has grabbed the foremost attention of scientists interested in people's behaviour in facing volcanic hazards (e.g. Murton and Shimabukuro, 1974; Greene et al., 1981; Perry et al., 1982; Johnston et al., 1999; Gregg et al., 2004; Dominey-Howes and Minos-Minopoulos, 2004). Risk perception is the estimated probability people have that hazards will affect them. Geographer R. Kates (1971) first lists a number of factors that may affect risk perception and develop this into a *human ecological* model of human adjustment to natural hazards. First are the nature and features of the natural hazard involved including its magnitude, duration, frequency and temporal spacing. Second are the frequency and intensity of personal experience of past, similar, events. Finally, personality factors like fate control, different views of Nature and the tolerance of dissonance-creating information are significant. Kates further underlines that these factors are independent from the socio-economic environment.

The role of cultural factors in shaping people's behavior in the face of natural hazards has been emphasized by anthropologists (e.g. Torry, 1979; Oliver-Smith, 1996; Oliver-Smith and Hoffman, 1999; Renn and Rohrmann, 2000). Cultural theorists emphasise that individual's decisions to face hazards of various origins are embedded in social and cultural values (Douglas and Wildavsky, 1982; Dake, 1991; Douglas, 1992). Both anthropological and sociological perspectives assert that people's behaviour is disconnected from the sole threat posed by the hazard to which the individual is exposed. The danger is rather filtered by an individual's perception of the world, which varies according to social values, religious beliefs, community traditions and attachment to place. Risks are here ranked according to the value given to threatened assets by a particular society. Objective risks may therefore differ from perceived risks. A significant set of studies have highlighted the role of those cultural factors in the face of volcanic hazards mostly in Southeast Asia and the Pacific (e.g. Belshaw, 1951; Keesing, 1952; Roger, 1981; Seitz, 2004; Gaillard, 2006, 2007). Chester (2005) further reviewed the importance of religion while Blong (1982) focused on legends in Papua New Guinea.

The weight of social and economic constraints has been emphasized by the proponents of a radical interpretation of disasters, which emerged in the 1970s (e.g. O'Keefe et al., 1976; Hewitt, 1983; Wisner et al., 2004). Proponents of this paradigm assert that people's behaviour in the face of natural hazards is often independent from natural hazards but constrained by social, economic and political forces beyond individuals' control. Disasters are viewed as the extension of everyday hardships wherein the victims are marginalized in three ways: geographically because they are forced to live in marginal hazard-prone areas, socially because they are poor and cannot protect themselves from natural hazards and politically because their voices are easily ignored (Wisner et al., 2004). This perspective emphasizes people's vulnerability or their susceptibility to suffer damage should natural hazards occur (D'Ercole, 1994, p. 87–88). Vulnerability thus stresses the condition of a society, which makes it possible for a hazard to become a disaster (Cannon, 1994, p. 13). People's vulnerability in the face of natural hazards, which includes people's well-being and strength, their livelihood resistance, their ability and willingness to protect themselves, the societal protection and the social capital among others (Cannon, 1994). Studies of people's

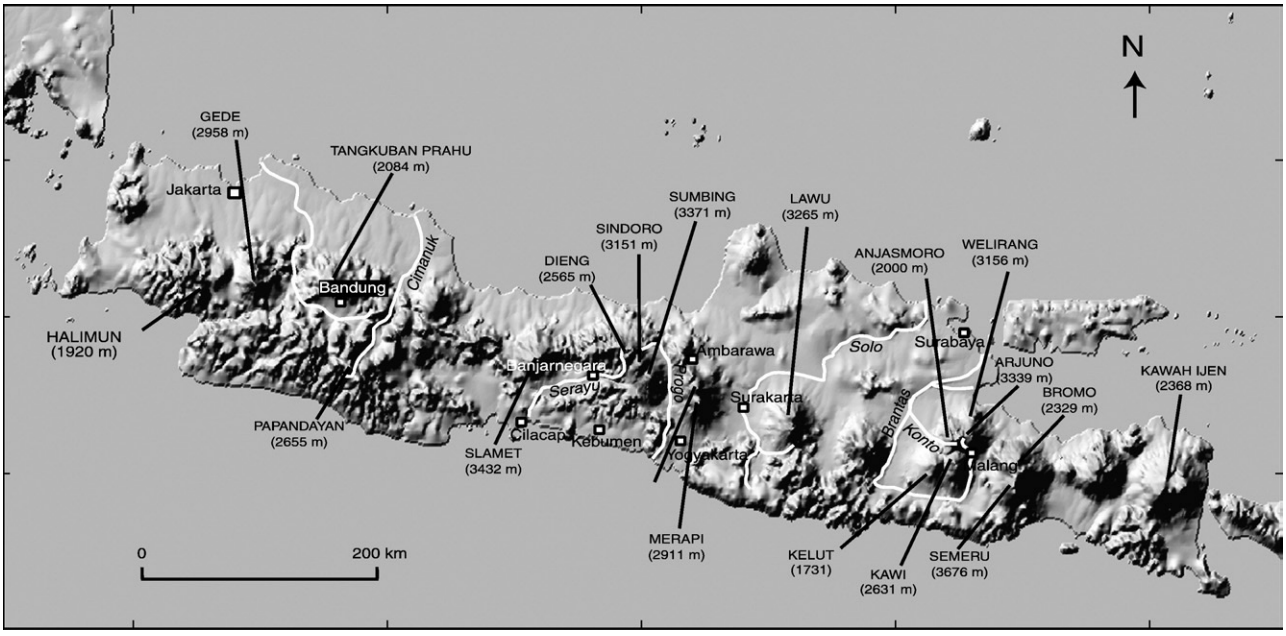

Fig. 1. Location of the main volcanoes in Java.

vulnerability in relation to social, economic and political constraints remain sparse (e.g. Chester et al., 2002; Dibben, 1999; Dibben and Chester, 1999; D'Ercole, 1991).

This paper particularly focuses on communities living around three Javanese volcanoes, respectively Mt. Merapi, Dieng Caldera and Sumbing and Sindoro twin volcanoes (Fig. 1). Java is the most densely populated Indonesian island and the locus of economic and political life. Furthermore, only a handful of studies address how Javanese people face volcanic hazards. Most deal with Mt. Merapi (Laksono, 1988; Schlehe, 1996, 2007; Dove, 2007, 2008-this issue). Noteworthy are two significant studies that address people's response to volcanic hazards in Bali (Coulonier, 1998) and Nila islands (Panell, 1999). The present studies aim to provide a comparative study of regularly active volcanoes. This enables an assessment of the role of hazard-related risk perception in contrast to hazard-disconnected cultural factors and socio-economic constraints. The first section of the paper will outline the methodology used for this study. The second section will describe how people behave in relation to the above-mentioned volcanoes and will investigate the importance of risk perception, cultural beliefs and socio-economic constraints. The discussion is a synthesis of the hazard-related and hazard-disconnected factors that influence people's behaviour around Indonesian volcanoes, aiming to place the empirical results into a conceptual context.

2. Materials and methods

Data presented in this paper came from several field studies carried out over the last 5 years. Questionnaire-based surveys and interviews with key informants were conducted among local communities during periods of volcanic quiescence on the slopes of Mt. Merapi, Sumbing and Sindoro volcanoes and in Dieng caldera. Surveys were adapted to each local context (Table 1).

Even if the structure of the questionnaires and interviews has changed from one survey campaign to another, all of them included questions which aimed to determine the level of perception of volcanic risk and behaviour in the face of volcanic threats. The surveys were designed to aid understanding of the factors underpinning the statements of awareness and perception (their own definition of volcano and volcanic risk, knowledge of eruptive past, causes of the eruptions, reactions in case of eruptive crisis, etc.). Some items gave information on demography and the socio-economic context in which respondents are living (age, sex, employment, study level, belongings,

Table 1
Survey methods at Sumbing, Sindoro, Dieng, and Merapi volcanoes

	Sumbing/Sindoro	Dieng	Merapi
Date of the study (month/year)	December 2003 to April 2004	January–February 2003	January–March 2002
Study location and justification of this choice)	8 villages or cities: Katekan, Gentingsari, Parakan, Kwadungan Jurang, Kwadungan Krincing, Garung, Tlahab, Wonosobo. Villages in the valley situated between both volcanoes. Location 8–10 km from the craters	4 villages: –Dieng and Dieng Kulon villages, close to the tourist spots Kawah Sikidang and Telega Warna – Kepakisan, close to Kawah Sileri which erupted in 1944 –Pekasiran village on the external side of the caldeira.	7 villages or cities: –3 villages along the Boyong River: Kaliurang, Turgo, Kardangan Slightly exposed to volcanic hazards prior to the 1994 Merapi eruption; –4 villages along the Krasak and Putih rivers: Tempel, Meijing, Sikaton, Kranggan Lor. Highly exposed to volcanic hazards – Distance to crater from 6 to 15 km
Number of surveyed people (questionnaires)	80 (0.1–2.5% of each village population)	116 (5–8% of each village population	80 (2–3% of each village population)
Number of interviewed people	32 interviewed people, 48 questionnaires+ 54 child draws	6 (filmed)	
Profile of the local community and on the surveyed people	2 urban communities (Parakan and Wonosobo), others are rural communities; 40% female; age and social level undifferentiated	–99% muslim –ages from 15 to 70 yr old. –78.4% men –74.2% farmers, 6.9% traders, 2.6% tourist officers, 1.7 motorcycle–taxi drivers	–Rural communities, mainly farmers. Limited contacts with the cities and the media. –Exception: sightseeing site of Kaliurang, with a volcanological observation post and civil defense. – Well-balanced sex ratio and age ratio
Objectives and structure of the questionnaire	–17 items 1–8: Risk knowledge and perception 9–12: cultural and non cultural factors 13–19: respondent profile	–46 items 1–5: landscape perception 6–12 risk perception 13–17: assessment of cultural factors 18–22: knowledge of protection tools 23–39: perception of recent environmental change 40–46: respondent profile	–65 items 1–14: respondent profile 1 5–35: risk knowledge and perception 36–41: access to information 42–57: knowledge of protection tools 58–65: people's behavior
Interviews with key informants	4 teachers; chief of the villages (kadus); chief of the volcanological observation post Gentingsari and volcanological office Yogyakarta	–Camat (sub-district chief) Batur and Dieng –chief of the villages (kadus) –chief of the volcanological office Yogyakarta	–chief of the volcanological office Yogyakarta and observation post Kaliurang –representative of civil defense Kaliurang, Balai SABO, Search end rescue and Satgas Kaliurang –2 military chiefs, districts Sleman and Magelang
Reference	Juvin (2004)	Flohic and Geyer (2003)	De Coster (2002)

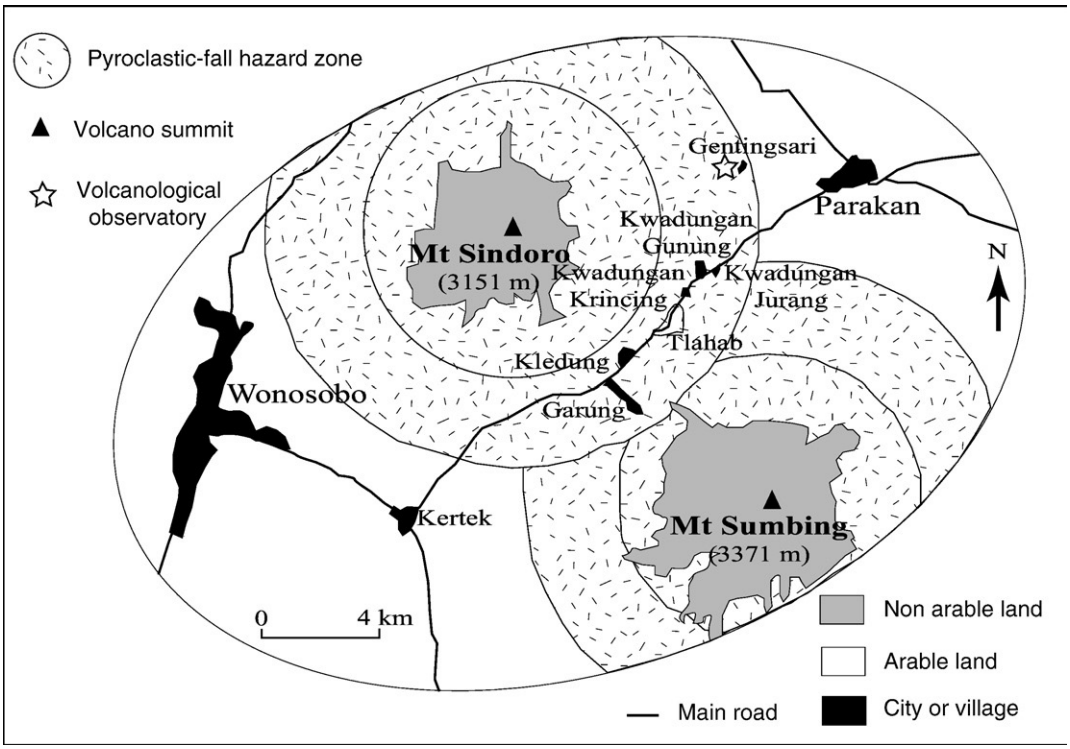

Fig. 2. Studied area around Sumbing and Sindoro twin volcanoes.

etc.). In addition to the data collected during these field works, F. Lavigne, P. Texier and B. de Coster provided unpublished data collected on the volcanic crisis of Merapi in 1994 and 2006.

3. Case studies at Sumbing, Sindoro, Dieng and Merapi volcanoes

3.1. The twin volcanoes Sumbing and Sindoro

Mt. Sumbing (3371 m. a.s.l.) and Mt. Sindoro (3151 m a.s.l.) in Central Java are active volcanoes although their activity has been very limited for one century. Sumbing has had only one historic eruption in 1730, which expelled a well-conserved lava dome and associated dome-collapse pyroclastic flows. Six small-scale eruptions have been reported for Sindoro since 1700. They were mainly phreatic (e.g. in 1906 and 1970), although they have expelled a small lava flow in April 1882 (Siswowidjojo and Matahelumual, 1972). However, large-scale eruptions have occurred during the last 10,000 yr. C14 dating of a tree fragment uncovered in a 12-m thick pyroclastic-flow deposit on the southern slope gave an age of 8165+/ 60 yr BP (CAL BC 7447-6868). Evidences of plinian eruption have been reported by McDonald (1972), and at least one debris avalanche may have occurred in the past (Mac Leod, 1989).

The results of our study show that only a few people are aware of the volcanic threat. Nobody in these communities fears the volcanoes. Consequently, 84% of the questioned people did not know the existence of the volcanological observatory or were not able to locate it, whereas it is located only 15 km from their village (Fig. 2). The collective memory has vanished over time and the risk has been forgotten, partly because the phreatic explosions that periodically occur within the Sindoro's crater are too small to be perceived by the villagers. Here risk perception is very dependant on the visual obstruction between the local communities and the active crater.

Among the people who are aware of the volcanic threat, risk perception is still poor. For example, 27% of the people said they would take refuge in the small cities of Parakan or Wonosobo in case of an outgoing eruption, whereas both towns are within the hazard zone delineated by the Directorate of Volcanology and therefore not safe (Fig. 2).

Hazard knowledge and risk perception in the local communities are closely linked to the Javanese cultural context. 70% of the people who were interviewed considered Sumbing and Sindoro as ordinary mountains, not as volcanoes, and therefore would not expect any volcanic activity. However, surprisingly, 60% of all people thought that both volcanoes were active. Such discrepancy indicates that people, aware of the volcanic activity, do not always use the term volcano to describe an active volcano. Conversely, when primary school pupils were asked to draw a volcano, 30% of them drew a simple mountain without any activity. Indeed, in the Javanese mental representation of the environment, a mountain (*gunung*) is often considered as a volcano (*gunung api* or mountain of fire) (Fig. 3).

A few stories or legends involving past eruptions have been reported on the slopes of these volcanoes (Juvin, 2004). One of them explains that the Sindoro crater moved to the Dieng caldera that is known to be very active. Six different villagers affirmed that Sindoro and Dieng volcanoes are geologically linked. If one of the Dieng's craters is blocked, the Crater of Sindoro will be reactivated. This idea of two connecting

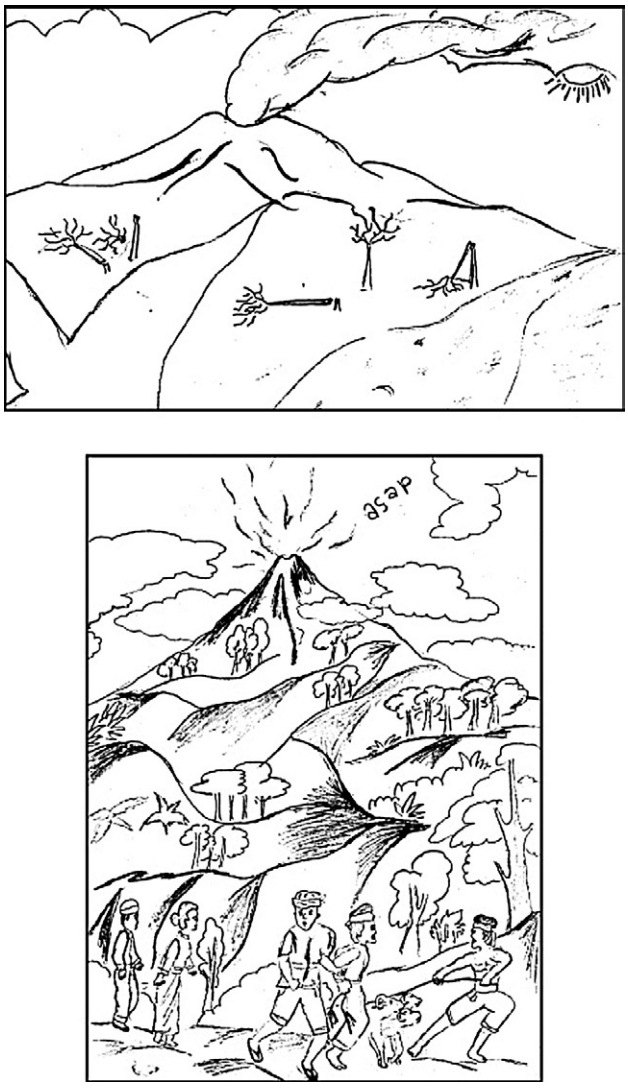

Fig. 3. Representation of a « mountain » in a village between Mt. Sumbing and Mt. Sindoro. Both drawings made by a primary school pupil show an active volcano. In the Javanese mental representations, the words "mountain" and "volcano" are not automatically dissociated. (Source: Juvin, 2004).

volcanoes was argued by population as a logical physical process. If the pressure was not relieved on one side, it has to be released on the other side. Consequently they believe that if one of the volcanoes is inactive, the other volcano has high probability of eruption. This type of explanation was also given to the 1970 hydrothermal activity in Sindoro's old crater (Le Floch, 2003) and the building of a thermal power station at Dieng.

As well as cultural beliefs related to the volcanoes, our survey emphasized the role of non-hazard related socio-economic factors in shaping people's behaviour in case of an ongoing eruption. For example, the physical status may play an important role. Interviews with key informants emphasised that women usually have lower hazard knowledge than men. Spending most of their time in the house or in the village—while men are working on the tobacco fields—women have a limited knowledge of the surrounding environment. None of them has ever climbed a volcano. Despite their low hazard knowledge, women report that they would probably evacuate more rapidly than men in case of a volcanic crisis, because the latter will stay longer to look after their house or livestock. Remaining in their hazard-prone villages would make male respondents highly vulnerable to an imminent eruption. The answers of the interviewed people underlined that livelihoods will play a key role in case of an evacuation order. In Kwadungan Gunung village, for example, farmers form 97% of the population. For poor people, food security will be more important than being exposed to a hypothetical volcanic hazard.

Since the early 1990s, many poor farmers have seen their income increasing with the upslope expansion of tobacco fields, (expansion of 600 ha/yr) (Lavigne and Gunnell, 2006) for at least three reasons: (1) almost all the lowland land suitable for agriculture is already used; (2) the demand for the region's well regarded tobacco is still high; (3) the quality of volcanic soils is still good for tobacco even at more than 1500 m. a.s.l. Therefore, many villagers are cultivating in hazardous zones.

It was particularly evident during the 1998 economic reforms, during which impoverished farmers encroached on forest lands to grow subsistence crops. At that time, volcanic risk was almost totally absent from local people's minds.

In the case of the Sumbing or Sindoro volcanoes, both hazard-related factors (low risk perception) and non-hazard-related factors (dependency on hazard-prone livelihoods and gender inequalities are of serious concern in the event of resuming volcanic activity.

3.2. Dieng caldeira: " *the abode of the gods*"

Dieng Volcanic Complex is a complex volcano, i.e. an extensive assemblage of spatially, temporally, and genetically related major and minor volcanic centers with their associated lava flows and pyroclastic rocks (Francis, 1994). The complex is expressed topographically as a highland plateau (2000 m.a.s.l.) about 14-km long and 6-km wide (Fig. 4). Considerable hydrothermal activity may have begun some 2500 yr ago. It consists of Solfatara and fumaroles, acid and near-neutral hot springs, which contain sulphur precipitates, mud pools at Sikidang, cold gassy mofettes, and also phreatic explosion craters. Small phreatic explosions frequently occur, e.g. in July 2003. Furthermore, CO2 flows or gas burst similar as the one that caused the Lake Nyos 1986' disaster in Cameroon have ever originated from the Sinila and Sigludug craters. The most recent lethal gas burst in 1979 asphyxiated 149 people caught in the gas cloud (Delarue et al., 1980).

Although considerable effort has gone into assessing the potential geological hazards in the area (Delarue et al., 1980), previous research has focused neither on risk assessment nor on risk perception of the local communities living within the caldera. Yet more than 500,000 people are living at high risk. The local communities on Dieng are aware of the natural hazards within the caldera. However, only 42% of respondents included the volcanic threat when asked to list the natural hazards on the plateau. Among the total listed natural hazards, the volcanic threat represented only 16%, behind landslides and poisonous gas, which were not considered to be of volcanic origin (Fig. 5). Similarly, although 53% of the people

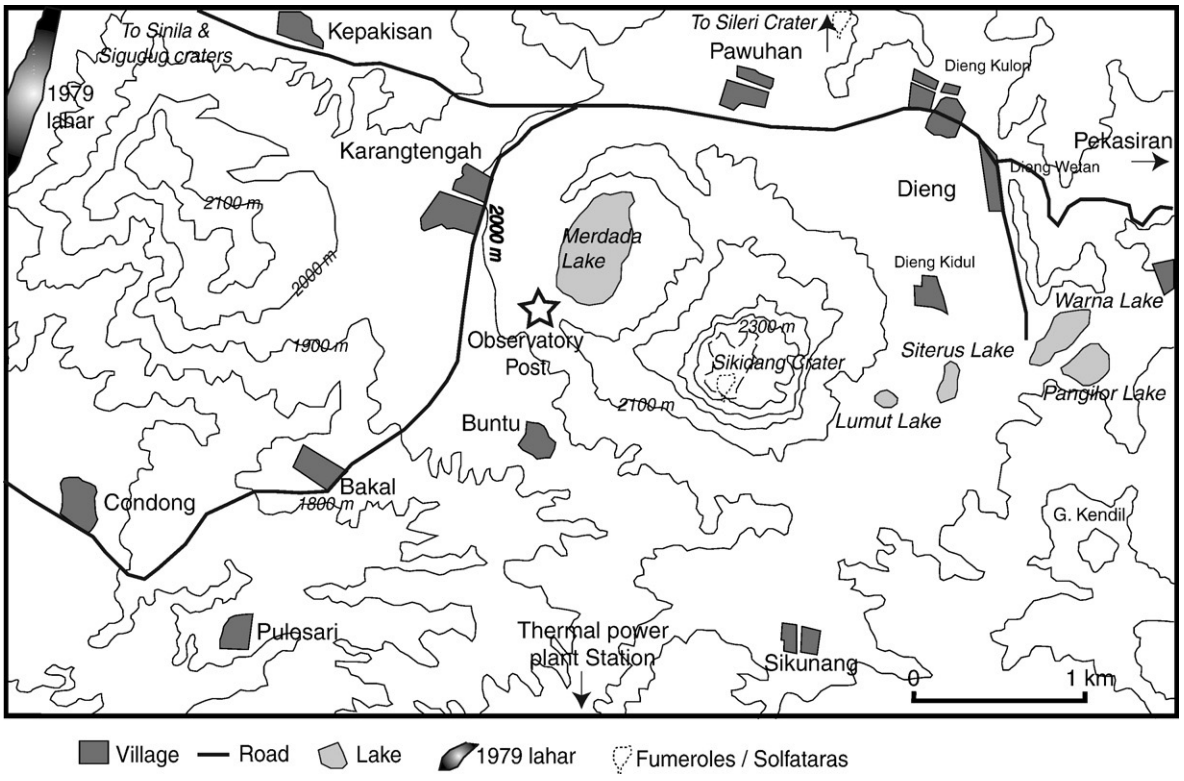

Fig. 4. Studied area within the Dieng caldera. This caldera is associated with the relics of two or more stratovolcanoes (Newhall and Dzurisin, 1988). The caldera is composed of late Quaternary to recent volcanic cones and explosion craters, some of which have been active during this century.

considered the 1979 lethal gas burst as the last major disaster-triggering event in the area, they were not aware that this event was accompanying a mild phreatic eruption. Our results have also revealed that 43% of questioned people were thinking that there are no volcanoes at Dieng.

These results do not really underline a poor knowledge of their environment by the local communities. They rather infer to a poor perception of the volcanic risk. Actually, the local people on Dieng are aware of the natural hazards within the caldera, but can hardly recognize them as of volcanic origin. Indeed, the words “volcano” or “volcanic eruption” usually refer in Java to some selected volcanic processes such as vertical magmatic explosions or pyroclastic flows. The cultural importance of Mt. Merapi, which will be discussed below, plays a key role influencing risk perception. As already noted in the case of Sumbing and Sindoro volcanoes, the word “active” is also difficult to interpret, even for people who are aware of the presence of volcanoes in the caldera. Referring to the question: “are the volcanoes active?”, 18% answer negatively, and 40% did not answer.

Even though more than 42% of the people answered affirmatively to the question “are you aware of the volcanic hazards in Dieng?”, their perception is not consistent with the real threat. For example, two-thirds of the questioned people in the four villages of Dieng, Dieng kulon, Kepakisan, and Pekasiran (Fig. 4) answered that their village could not be affected by any volcanic event, whereas the surrounding villages are threatened. People are aware of the volcanic threat, but do not feel personally concerned by this threat, contrary to other environmental hazards like deforestation (89% of the interviewed people were aware of this threat: Flohic and Geyer, 2003) or soil erosion (erosion rates reach 400 t ha-1 yr-1 in potato fields: Lavigne and Gunnell, 2006). Indeed, the environmental hazards like erosion and deforestation directly damage the daily resources and the income of the local communities (Flohic and Geyer, 2003).

The cultural history of the area and local cultural beliefs may partly explain this lack of fear. The original seventh century Hindu inhabitants referred to “Dieng”, meaning “the abode of the gods”, because of its proximity to the volcano. Among

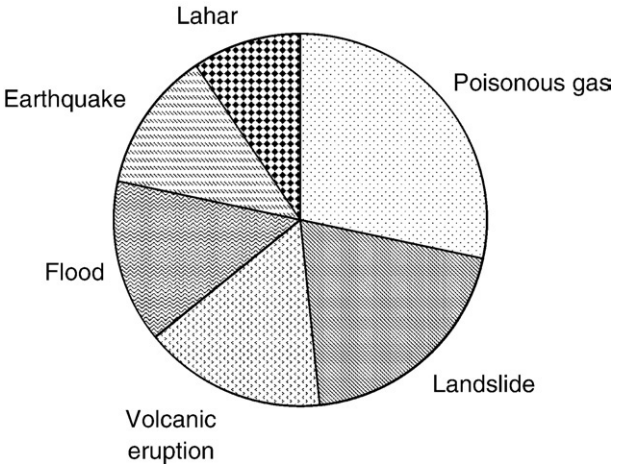

Fig. 5. Perception of natural hazards in the Dieng caldera in 2003. Inquiry among 116 people who were allowed to suggest several answers.

hundreds of temples supposed to have been built in Dieng in the 7th and the 8th centuries, only eight remain in a good state of repair. Nowadays, Islam has become particularly strong in Dieng. For historical reasons, the caldera is still a sacred land for at least 12% of those people questioned, and 70% though that potential loss are under the control of divine forces. Claiming that Dieng is the land of their ancestors, 20% of the questioned people will refuse to leave definitely this place. Such beliefs may increase the vulnerability of the local communities (Schlehe, 1996, 2007; Dove, 2007, 2008-this issue).

The socio-economic environment also acts in a similar way. The Hindu temples of Dieng are scattered in a spectacular landscape, which make it a well-known tourist destination (70,000 tourists listed in 2002). Based on discussion with tourists, only a few of them are aware of the volcanic threat. Dieng plateau is also a rich agricultural area. With the goal of enhancing their income, the farmers have expanded the potato fields within the danger zone since the early 1990s (Lavigne and Gunnell, 2006). In 2001, the average annual takings of a potato planter at Dieng reached 26 million rupiah (i.e., 2000 euros), which is equivalent to the annual income of a university professor in Indonesia. As in other mountains of the Tropics, this phenomenon is related to the rising demand for cool climate fruit and vegetables from corporate multinationals and from the population of the rapidly growing cities. Although poisonous gases frequently kill the farmers near the Sinila crater and other sites, local people consciously accept this risk. Trust in the scientists and the local authorities have sometimes influenced people's risk perception. For example, forty-seven families from Dieng caldera who have migrated after the poisonous gas emission from the Sinila crater in 1979 returned to their former village after learning that their land did not lie within the designated danger zone (Laksono, 1988).

3.3. Merapi: one of the world's most active volcanoes

Mt. Merapi is the southernmost of a N165°-trending chain of stratovolcanoes (Fig. 1). For the last two centuries, the activity of Mt. Merapi has alternated regularly between long periods of viscous lava dome extrusion and brief explosive episodes at 8–15-yr intervals, which generated dome-collapse pyroclastic flows and destroyed part of the pre-existing domes. Violent

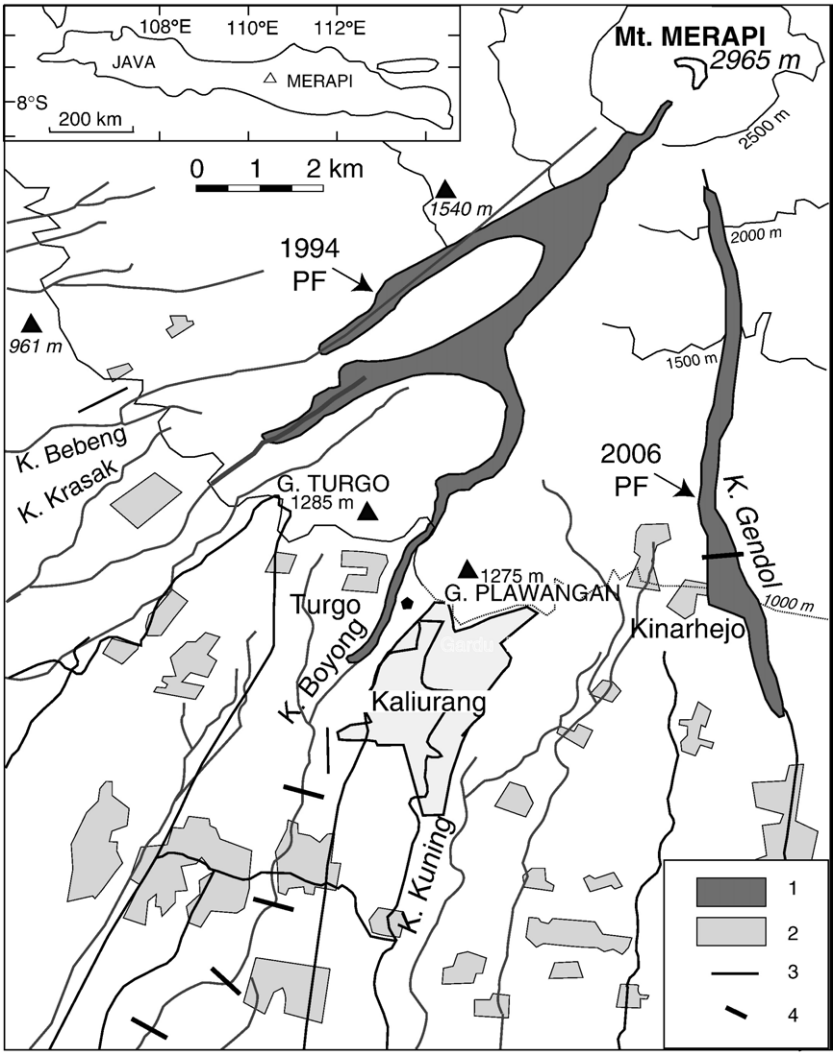

Fig. 6. Studied area on the southern flank of Merapi volcano. 1: block-and-ash flow deposits; 2: village; 3: road; 4: retention dam.

explosive episodes on an average recurrence of 26 to 54 yr have generated pyroclastic flows, surges, tephra-falls, and subsequent lahars (Thouret et al., 2000). The 61 reported eruptions since the mid-1500s killed about 7000 people. At least one large edifice collapse has occurred in the past 7000 yr (Newhall et al., 2000) or more probably between 10,000 and 12,000 BP, when a lake formed around the present Borobudur temple (Gomez et al., 2006).

In 1995, the Merapi volcano was supporting about 1.1 million inhabitants in 300 villages located higher than 200 m.a.s.l. Among them, 440,000 people were at high risk in areas prone to pyroclastic flows, surges, and lahars (Lavigne, 1998). This volcano is one of the most observed and studied over the world. We analysed people's behaviour, hazard knowledge and risk perception before, during and after two eruptions of Mt. Merapi. Pyroclastic flows occurred in the Boyong River in November 1994 and in the Gendol River in June 2006 (Fig. 6). Prior to the 1994 dome-collapsed pyroclastic flows and its associated ash-cloud surges that killed 69 people at the Turgo village, people living along the Boyong River were not aware of any hazard in their village (Schlehe, 1996, 2007). Interviews with key informants living along the Gendol River show that similar feeling of safety persisted until the 2006 dome collapsed in this channel. Discussions with local people attest that the time lapse since the last pyroclastic flow occurrence at the beginning of the 20th century is one of the main reasons for this lack of hazard knowledge in both cases. However, more than 8 years after the 1994 eruption, 93% of the villagers interviewed at Turgo thought that they would not be personally affected by a future eruption of Mt. Merapi (De Coster, 2002).

This feeling of safety is enhanced with the distance of the village from the crater. The further the village was from the active vent, the less the risk awareness there was. In 2002, the percentage of people who could differentiate lava flow, pyroclastic flow and lahars through comparative pictures of the processes was quite high at Turgo and Kaliurang—65 and 80%, respectively, both located at 6 km from the crater, whereas this ranged from only 17 to 27% at Kardangan, Kranggan Lor and Srikaton, located at 11 and 15 km from the summit.

The feeling of safety may be influenced by a visual obstacle between the village and the active vent. Based on our field surveys in 1994–95 and 2006, local people of Turgo and Kaliurang villages were feeling protected by the Turgo and Plawangan hills before and at the beginning of the 1994 eruption. Prior to the May 2006 eruption of Mt. Merapi, local informants living along the Gendol River thought they were protected by a remnant of the 1910 lava dome called Geger Buaya. Unfortunately, the increase in volume of the new lava dome had caused Geger Buaya to collapse on 4 June 2006. Four days later, pyroclastic flows started entering the Gendol valley.

In spite of a good awareness of the volcanic threat, the local communities often perceive the risk as acceptable, because they under-estimate the predicted or probabilistic risk, in the sense of Renn and Rohrmann (2000, p. 14). They can estimate neither the probability of volcanic hazard activity occurring, nor its consequences, due to a lack of knowledge of volcanic processes. For example, during the 1994' eruption of Mt. Merapi, some people were shouting "lahar, lahar..." when they saw pyroclastic flows entering the Boyong valley; those aware of the volcanic hazard did not realise that pyroclastic surges were able to flow over small hills; in 2006, they did not expect that an old lava dome might collapse. Informants acknowledge that they are not aware that the volcanic hazards and the channels prone to pyroclastic flows may evolve over time, unless they have visually observed such dynamics.

As already observed at Sumbing, Sindoro, and Dieng volcanoes, the cultural environment may influence people's behaviour and perception of the risk. Around Merapi volcano, religious beliefs had animist, Hindu, Buddhist and Muslim influences. The influence of religion is evident in the large proportion of people (97% of those surveyed) who think that actual and potential loss associated with volcanic eruptions are under the control of divine forces (De Coster, 2002). Especially in Java, spirit cults, ancestor worship, spirit healing and shamanistic forms ('dukunisme'), and mythical traditions are widespread and enjoy much popular support, especially in rural areas (Triyoga, 1991; Schlehe, 1996, 2007; Dove, 2007, 2008-this issue). The 22 November 1994 eruption of the Merapi volcano precipitated a spontaneous revitalization of old myths and mystical beliefs and gave impulse to the government's efforts to have inhabitants migrate away. Neither villagers living on the slopes of Mt. Merapi nor the inhabitants of Yogyakarta regard the eruption primarily as a disaster. Rather it is understood as an admonition from the supernatural world (Schlehe, 1996). As a result many people living close to the Boyong and the Gendol rivers are not fearful. This volcano's permanent activity has been totally integrated in people's daily life, and has become an informal part of it. Mount Merapi is personified: "Mbah Merapi"—Mbah means grandfather or grandmother—belongs to the human world. Instead of being considered a source of danger, the volcano embodies the common patriarch respected by all the villagers. The Javanese term *wedhus gembel* (pyroclastic flow) is considered as impolite for some people who prefer to used the Indonesian expression *mengeluarkan kotoran*, i.e. to expel excrements, like humans do.

There are two cultural leaders in the traditional Javanese religion (*Kejawen*): the sultan of Yogyakarta and the *Juru Kunci*. The *Juru Kunci* is the key holder of the volcano. He communicates with the spirits who look after the mountain. On the slopes of Mt. Merapi, local people put their trust in the local mystic *Juru Kunci*, Mbah Marijan. During the last Merapi eruption in April 2006, Marijan refused to evacuate although he supported an evacuation for other people. He got in touch with the spirits of nine ancestors (*pepundhen*) after 3 days of meditation in order to ask Mt. Merapi to limit the level of destruction. This man of almost 80 yr received a continuous parade of visitors seeking information about the mountain at his small home in the Kinahrejo village. He was appointed by the sultan to carry out annual offerings to the volcano, a century-old tradition (Triyoga, 1991). The presence of the *Juru Kunci*'s house at Kinarhejo partly explains the refusal of the inhabitants to evacuate before the 2006 eruption of Mt. Merapi, although the evacuation had been ordered by the authorities. The distance

between the village and the *Juru Kunci*'s house at Kinahrejo (Umbulharjo, Southeastern flank of Mt. Merapi) influences the kind of risk perception. Indeed, people living close to Kinahrejo mainly trust the *Juru Kunci* and feel protected, whereas people living far away from him at the same distance from the crater (e.g. at Tungularum village, Wonokerto, on the Southwestern flank of Mt. Merapi) have less confidence in his supernatural power.

Actually, although many people living on the volcanic slopes still have animist convictions and worship spiritual gods, most of them also listen to the local authorities and the scientists. During the warning that preceded the 2006 Merapi eruption, only a few of the 25,000 people at risk, including the *Juru Kunci* and other people from his village Kinahrejo, refused to evacuate. At Selo and Boyolali, on the northern flank of Mt. Merapi, local people even left before the official warning. Therefore, it seems than the influence of the cultural factors on risk perception and on people's behaviour has decreased a little since the 1990s when described by Schlehe (1996).

The sultan of Yogyakarta, who represents the link between the traditional and modernity, may have played a key role in this change. He has actively participated in the success of the evacuations in 2006, because he explained the necessity to evacuate the local people against the advice of the *Juru Kunci*'s. The sultan's house at Kaliurang (*Sanggrahan*) is supposed to protect the village. It is believed to have diverted the 1994 pyroclastic flows onto the Turgo village, where the local people felt themselves protected by another sacred site: the grave of the sheik Maulana kubro at the summit of Turgo hill. The Sultans of Yogyakarta as the direct descendants of Brawijaya, the last king of the Majapahit dynasty, are obliged to honor their ancestor by making offerings (*Labuhan*) in sacred sites like Mt. Merapi (Fig. 7).

People's behavior in the face of volcanic hazards also varies according to their livelihoods and resources. Indeed, although aware of an ongoing hazard, the poorest farmers or stock-breeders will sometimes be more reticent to evacuate than the other villagers because they may lose access to their only daily resources. At the village of Turgo after the 11 November 1994 eruption, the poor villagers came back daily to their village despite it being banned by the authorities. During the long Merapi eruption in 2006, three types of behavior were noticed following the evacuation order by the local authorities: (1) some people—mainly women, children, and the elders—stayed in the refugee camps. (2) At Kaliurang, about one fifth of the population—exclusively male—stayed in their village day and night to keep out looters. People from Kinahrejo also left the refugee camps, returning to their homes to earn an income, feed the farm animals, or establish their food security. Indeed, people felt that the probability of theft was higher than that of being injured or killed in a pyroclastic flow, although more than 60% of the villagers were aware of the volcanic threat. (3) Other people who had no saved money—mainly 20 to 50 yr old males and females—chose to stay in the refugee camps at night and to go back during the day to their villages.

The influence of the level of education on peoples risk behaviour is difficult to assess. Our field data along the Boyong River (De Coster, 2002) challenges the common belief that

Fig. 7. *Labuhan* ceremony on the southeast slope of Mt. Merapi, August 2006. (Photo: P. Texier) The rituals are conducted in accordance with the long years of inherited tradition. Usually, many people attend the ceremonies, wishing to get a blessing from the Creator of the world. At Mt. Merapi, the offerings are meant to honor the Lordly grandfather Prince Sapujagad, a great respected leader of the founding fathers of the second Mataram Kingdom. In the evening, a proper preparation followed by a prayer is held in Kinahrejo. The offerings or *tumpeng* are believed to protect what was once the kingdom of Yogyakarta from eruptions. A *tumpeng* often represents a mountain of rice or vegetables with the shape of a volcanic cone.

people with higher education have a more accurate perception of threat. Highly-educated tourist traders of Kaliurang might be expected to have a better understanding of the warning messages. If a warning signal is launched however, many of them indicated that they would approach the Boyong valley to see the pyroclastic flows for their own eyes before escaping. This attitude, which would put their life in danger, can be explained by the high value of the goods they will have to abandon temporarily (house, goods, work tools, etc.). On the contrary, farmers with little education usually have a good knowledge of their environment and of the natural threats. They will therefore often start an escape more rapidly,—particularly since they have little goods to lose—even though they will come back in their village sooner than others.

On Mt. Merapi, local authorities have had difficulties in moving the 80,000 people away from the so-called "forbidden zone" where they live (Lavigne, 1998). Due to the exceptional quality of the volcanic soils and the cooler climate on the mountain slopes, people have progressively cut the montane forest and built thousands of villages at high elevation (Lavigne and Gunnell, 2006). The villagers do not ignore or deny the importance of the volcanic threat; they merely do not consider it sufficiently important to justify moving away from the mountains. Implicitly, they do not consider the volcanic risk to be greater than the threats they would face in an alternative place of residence.

4. The role of risk perception, cultural beliefs and socio-economic constraints in people's behaviour in the face of volcanic hazards

The present study explored the role of three factors in shaping people's behaviour in the face of volcanic hazards

based on three case studies from Java. These three factors are hazard-related (risk perception) and non hazard-related cultural beliefs and non hazard-related (social and economic constraints). Perspectives from Sumbing and Sindoro twin volcanoes, Mt. Merapi and Dieng caldera provide unique evidences to weight the role of each factor. In all three cases indeed, people choose to live in hazard-prone areas in massive numbers.

4.1. Risk perception

The three case studies from Sumbing and Sindoro twin volcanoes, Mt. Merapi and Dieng caldera show that people are fully aware of volcanic hazards in their immediate environment but few of them perceive them as risks for themselves. This concurs with many volcanic risk studies which linked 'poor' risk perception with dangerous behaviour in the face of volcanic hazards (Johnston et al., 1999; Gregg et al., 2004). However, the present study shows that in the Javanese case, low risk perception is not linked to poor hazard knowledge. This startling observation does not fit conventional explanations to low risk perception. The literature indeed insists on a correlation between hazard knowledge and risk perception (e.g. Kates, 1971; White, 1974; Blong, 1982).

We have found:

(1) A poor understanding of the actual volcanic processes beyond the knowledge that they exist. There are several reasons for this gap between actual hazards and known hazards. First is the source of information on hazard and risk. In Java, hazard knowledge is transmitted through different sources, either outside or within the village at risk. External stakeholders involved in the knowledge transmission are teachers, journalists or local authorities. Internal actors include the elders, who have more chance than young people to have witness a volcanic eruption in the past or to have heard about former eruptions by their ancestors. Our three case studies show that the basic knowledge that teachers, the elders and the media transmit to the local people at risk is insufficient to anticipate the consequences of a volcanic eruption.

The second factor is the personal experience of the local people. This does not always involve the whole range of hazards, and the volcanic processes may vary between two eruptions of a single volcano. At Merapi, the local people are not aware that future pyroclastic flows may affect some valleys that have not experienced events in the past. The poor knowledge of the actual volcanic process is also closely linked to the distance between their village and the active crater. The local communities living further than 15 km from the Merapi crater can not imagine that such a distance may be reached by future pyroclastic flows. This feeling of safety is enhanced by the extent of the pyroclastic-flow hazardous areas delineated by the Directorate of Volcanology and Geological Hazard Mitigation (DVGHM). However, the hazard maps drawn by the DVGHM, e.g. the Merapi hazard map, do not take into account the possibility of a major explosive eruption (Thouret et al., 2000).

The geographical origin of the villages plays an important role as well in people's differing knowledge of volcanic hazards. People living in their birth village usually have a better knowledge of their environment, especially if they have already experienced previous eruptions or other natural hazards. In contrast, new migrants coming from a relatively safe area have a low perception of risk. For example, sand miners working in the valleys of Merapi are often trapped by lahars because most of them come outside the area and lowland farmers without any knowledge of volcanic threat have recently colonized the highest slopes of the Javanese volcanoes in the context of the 1997 economic crisis.

(2) An excessive trust in countermeasures. The feeling of safety of the local communities is enhanced by technical countermeasures against volcanic hazards, e.g. drainage tunnels out of crater lake (e.g. at Kelut volcano), concrete dykes along river banks prone to lahar overflow, protection dams, etc. Technical mitigation measures that increase objective safety may lead to overconfidence and risky behaviour (Adams, 1995). For example, people living on the upper flanks of Merapi volcano feel protected from the pyroclastic flows by the Sabo dams, whereas such concrete structures tend actually to raise the riverbed and therefore to increase the pyroclastic surge hazard.

An early warning system network also provides a feeling of security. In 2002 at Merapi, more than 70% of the villagers thought that the traditional *kentongan* (drums) were an efficient system. However, only 46% of them were aware of the codes related to a volcanic eruption.

All three case studies of Javanese communities show that low perception of risks associated with volcanic hazards is more than a simple mismatch between actual hazards and known hazards. Our study suggests that there are other risks connected to non-hazard factors which weight heavier than volcanic risk perception in shaping people's behaviour.

4.2. Cultural beliefs

The link between the Javanese people and their volcanic environment is very strong. The village they live in and the land they cultivate are also those of their ancestors. The local people are therefore strongly attached to their birth village (Koentjaraningrat, 1985). For that reason, people are often reticent to evacuate and/or in a hurry to come back home after having being moved by the local authorities.

This attachment to place is also conditioned by deeper beliefs related to the mental representation of volcanoes. In Sumatra the Batak people around Mt. Sibayak, Mt. Sinabung and Toba Lake are descendants of former sailing communities, as seen in the shape of the roofs of their traditional houses. Therefore, the volcanic risk is less-present in their traditional beliefs than it is in Java, where the world representation is centred on volcanoes. Although Java's latter-day Islamic society has largely replaced earlier cultures-each having added to a tapestry of truths, half-truths and myths, Hindu and Buddhist cosmogonies are still vivid. The complexity of syncretic spiritualities plays an important role in shaping reactions. On volcanic slopes where Islam is quite strong like in Dieng, some religious leaders claim that the eruptions are warnings from God about the evils of drinking strong liquor or other sins such as prostitution. Similar

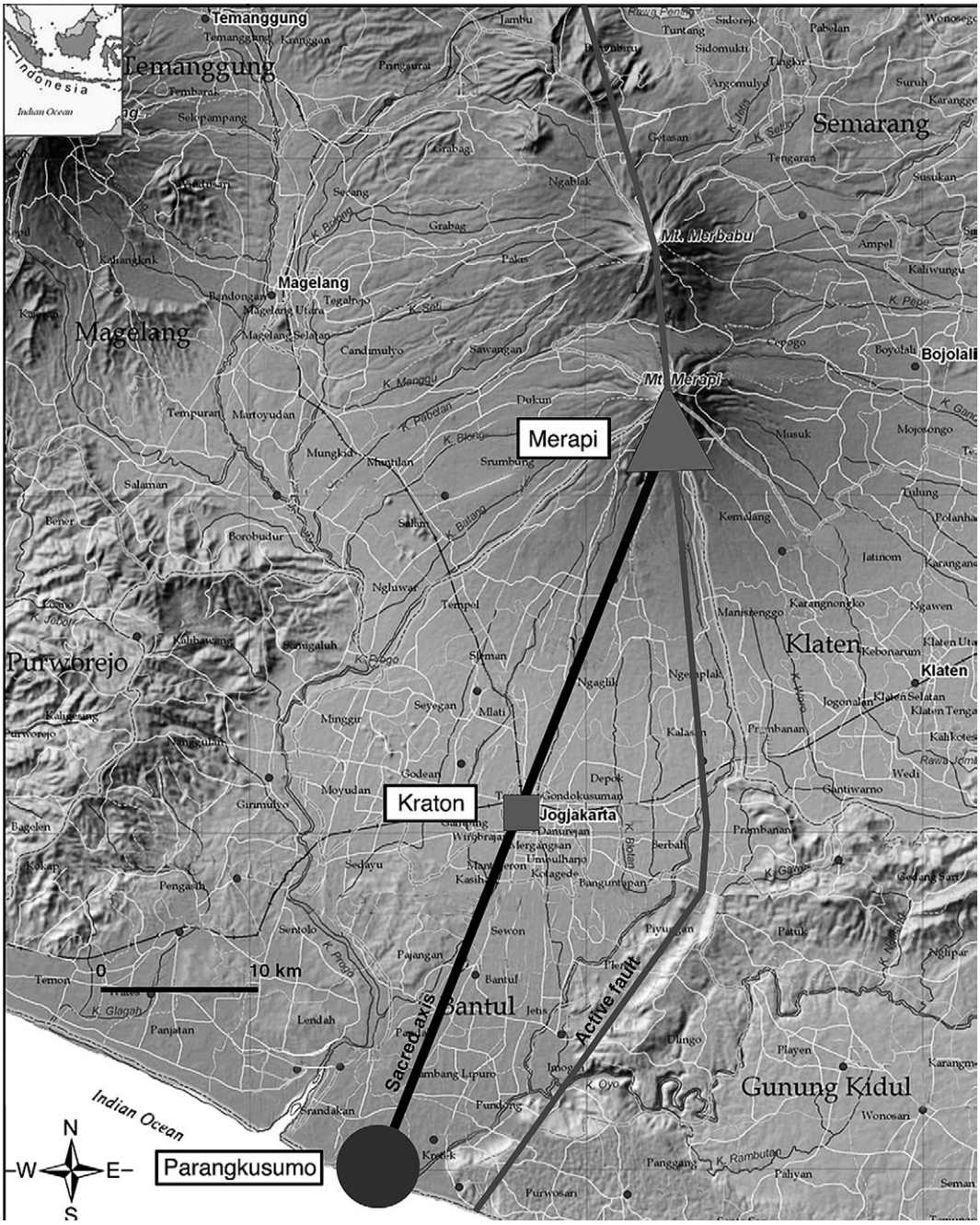

Fig. 8. Axe Merapi Parangkusumo. The old fault from Merapi to Bantul, which was reactivated during the May 2006 earthquake, is parallel to the sacred north–south axis between Merapi and Parangkusumo beach. The presence of another fault from Mount Merapi to Mount Lawu may explain why the Lawu is the fourth important element in the Javanese world representation.

ideas were spread by a radio evangelist following the eruption of Mt. Saint-Helens in 1980 (Blong, 1984), or at Banda Aceh following the 26 December 2004 tsunami. At Merapi, some of the nearby villagers are distrustful of modern science and the government, turning instead to beliefs steeped in ancient Javanese mythology (Schlehe, 1996).

Almost all the Indonesian volcanoes have their own legends, which usually involve gods, princes and princess, and mortals (Mathews, 1983). In the Javanese cosmology, the sacred and the profane are incorporated into a single conceptual framework. Important relationships between natural elements are generally understood in terms of a binary scheme of complementary but opposite poles, which are linked by relationships of exchange. The best example of this relationship is the volcano–sea polarity mediated by the river traversed hills and plains in between. In the Javanese cosmogony, the Indian Ocean is the home of Ratu Kidul, the Princess of the South, who is renowned for influencing the Merapi activity. The opposite poles are usually linked by a spiritual line, which often corresponds to active faults (Fig. 8). Indigenous settlement patterns are usually derived from cosmological features or idealised relationships. Often the two are linked together in a single ordered scheme (Fig. 9). The Wayang Kulit, a traditional

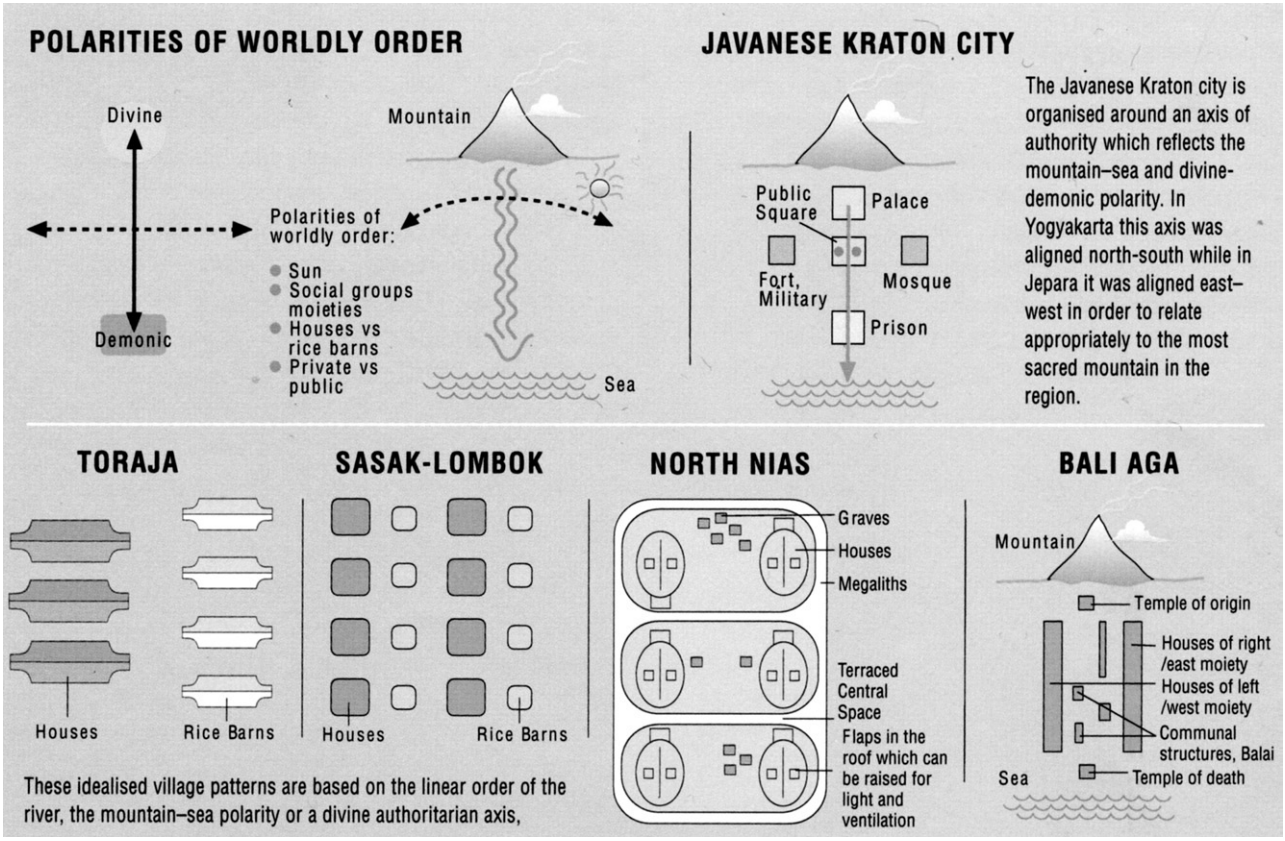

Fig. 9. Idealised village patterns in Indonesia. (Source: Riggs, 2003). The construction of Boroburur and Mendut Buddhist temples in Central Java is based on an idealised mountain–sea polarity. They were built on a spiritual line where other smaller temples lye between the Merapi and the sea. This symbolic of a cosmic mountain has been used by the Hindu and Buddhist temples, which are considered as the meeting points between the gods and the Humans (Boomgaard, 2003, p 301; Dumarçay, 1986, p 88–91; Sevin, 1992, p 117). The Kraton city, where the sultan lives, is also organised around an axis of authority, which reflects the mountain–sea polarity. In Yogyakarta, this axis was aligned north–south (Fig. 10) while in Jepara it was aligned east west in order to relate appropriately to the most sacred mountain in the region. The Balinese villages were built with the same cosmological concepts.

Javanese shadow-play with flat leather puppets, encompasses a famous puppet which represents an imaginary mountain called *Gunungan* (mountain) or *Kayon* (tree). The *Kayon* shows two opposite faces: the Tree of Life, and the Tree of Death (Fig. 10). Both faces of volcanoes—the tree of life and the tree of death—are represented in the Javanese and Indonesian word *korban*. This word means both victim and sacrifice. When the villagers are beyond reproach, they interpret the destruction from an eruption by the fact that the volcano needs to prepare a reception.

One characteristic of Indonesian societies is that deities are invoked as the causal agents of death and destruction, frequently engendering responses of passive acceptance. However, death and destruction do not have the negative connotation as these words have in Occident. It's a regenerative destruction, a death which aims at aborting the rising evil and at reconstructing on wholesome basis. What's more, the passive acceptance should not be interpreted as fatalism conveying the powerlessness of Humans in the face of the Nature. It renders rather a sign of Humans humility and their search of peace and harmony.

4.3. The importance of social and economic constraints

Although factors of personality and psychology might affect an individual's perception of volcanic hazard, as exemplified in Hawaii (Murton & Shimabukuro, 1974), social and economic constraints are more important factors in the Javanese context. These constraints are twofold and include traditional Javanese social structure and difficulties in accessing livelihoods.

The social structure of the village is an important factor in shaping people's behaviour in the face of volcanic hazards. As observed on Santorini, Greece (Dominey-Howes & Minos-Minopoulos, 2004), residents aged N50 have retained a memory of the effects of the last eruptions, whereas younger residents have no such knowledge. When facing a volcanic eruption, people will not react individually only in relation to their age or sex. The decision to evacuate or to come back to a hazardous area after having moved or emigrated is usually taken as a community decision, where the chief of the village (*kepala dusun* or *kadus*) plays a more important role than the one played by the authorities. For example, all those surveyed at Merapi indicated that they would be looking for some information before evacuating: 37% would ask the village chief, 35% to some friends, neighbours or family members, and only 25% to the civil authorities or civil defence (De Coster, 2002).

Access to livelihoods appeared to be the main non hazard-related factor for all of our case studies. At Merapi, where people's density within hazardous areas exceed 500 per km^2 (Lavigne, 1998), poverty and food security are the main reasons

Fig. 10. Imaginary mountain in the Javanese wayang kulit: the Kayon/Gunungan (Photo: B. De Coster). Wayang kulit theater portrays the essence of the Javanese world view. Life is fleeting and changeable, not controlled by mortals or even the gods, but manipulated by some cosmic puppet master. The Javanese are too subtle to imagine that human nature is all bad or all good—even the great heroes have certain weaknesses, and some of the villains have great nobility. The Tree of Life symbolizes the nourishing mountain, which feeds the plants and the villagers. A tiger looks after the sacred mountain. At the bottom in the middle of the *gunungan*, a door symbolizes the path between the human world and the worlds of deities and spirits. The mountain is the border between both worlds. This door also represents the entrance of the sultan's palace inasmuch as the sultan is the mediator between the Humans and the Gods living in the mountain. The other face of the mountain represents destruction and death, symbolized by fire, flames and lava, which go out from the volcano's mouth. The volcano keeps an eye on the Humans and is watchful of their behaviour. Wild animals and invisible creatures (spirits, ghosts, *tuyuls* etc.) are the volcanoes custodians.

to push the villagers to live within the hazard zone. However, the well-off potato planters on Dieng also perceive the threat and accept that they will have to live at high risk. Indeed, the active volcanoes are a source of income for millions of people in Indonesia. Thousands of sand miners who work in the channels conveyed by lahars at Merapi are also aware of the risk to their lives in the event of volcanic activity. However, inasmuch as their income is about three times higher than that of the lowland rice farmer, local people accept the risk. Every year, lahars destroy trucks on the southwest flank of Merapi, and tens of workers have already died. When a volcanic crater has been developed for tourism and is therefore accessible by car, hundreds or even thousands of local people spend most of their time within the most dangerous area, e.g. at Tangkuban Prahu, Bromo or Dieng caldera. Additionally, from the 70,000 tourists listed at Dieng in 2002, only a few were aware of the volcanic threat.

A few kilometres away from the active craters, the mountain forests have become the last frontier of colonisation in Java as observed in the context of the 1997 economic crisis (Lavigne & Gunnell, 2006). Everywhere on the island, forest clearance on the volcanic slopes has reached its highest rates since the colonial period. The flanks of the Sumbing and Sindoro volcanoes give a clear example of forest decline since the 1980s. With the aim of increasing their income, the farmers of Dieng caldera have expanded the potato fields within the danger zone since the early 1990s. Based on field survey, 70% of local people consider the Dieng caldera as a potentially prosperous and fertile area. Although poisonous gases frequently kill the farmers near the Sinila crater, they accept this risk.

In time of crisis, people's behaviour is similarly constrained by economic pressure. For example, after the 1994 and 2006 eruptions of Merapi, the poor villagers along the Boyong River came back daily to their village despite the ban from the authorities. They felt that the threat from looting was worse than that the risk of being killed by the volcano. When financial or other limitations restrict livelihoods in order to reduce or avoid this risk, people sometimes live with a higher risk level than those they usually find acceptable.

5. Conclusion

Three case studies from Sumbing and Sindoro twin volcanoes, Mt. Merapi and Dieng caldera showed that the Javanese people's behaviour in the face of volcanic threats is shaped by the complex interaction between perception of risk associated with volcanic hazards, cultural beliefs and socio-economic constraints. In Java, the need for securing daily livelihoods prevail over volcanic risk perception while religious beliefs enable people to cope with the threat by providing alternative explanations in time of disaster. Risks linked to volcanic hazard can therefore not be dissociated from their socio-economic and cultural context. Recent studies came to the same conclusions in the Philippines (Gaillard, 2008-this issue) and in Ecuador (Tobin and Whiteford, 2002; Lane et al., 2003), Tonga (Lewis, 1999) and Italy (Dibben, 2008-this issue).

Yet, as elsewhere in the world, the Indonesian official disaster management framework largely overlooks contextual factors and remains focused on hazard-related factors. The actual warning system and the evacuation plans are based only on the level of volcanic activity and on the hazard maps that have been drawn by the DVGMH. In this context, the risk perception of the local communities living outside the official hazard zone is poor. In addition, the present study suggests that effective risk and disaster management should go beyond the sole consideration of volcanic hazards and related factors such as risk perception. Chester (2005) recently called for a revision of the current approach of volcanic risk management to integrate the study of the wider culture and society. The Merapi case particularly suggests that religion is an essential element of culture and must be carefully considered in the planning process, and not simply dismissed as a symptom of ignorance, superstition and backwardness. Similarly, access to livelihoods is instrumental in the choice of people to face volcanic hazards. Indeed, poverty and food insecurity are an everyday hazard while volcanic phenomena are rarer hazards and those less

significant if people's decision making process. Finally, people's risk perception should be integrated in disaster management policies. Today, differences in the perception of risk associated volcanic eruptions in Indonesia may become a source of conflict between the central government and the local population. Volcanic risk is usually identified by both the threatened people and the local authorities but perceived in different ways. They differ less because of a miscalculation of the threat than because of the relative weight placed upon it. Scientific knowledge and traditional cultural knowledge both have elements of subjectivity.

However, representations of the volcanic environments are evolving with modernization, industrialization, increase of education, progresses of science, etc. New cultural values progressively spread over Indonesia. It is therefore a great challenge to try to assess people's vulnerability and risk perception, as it evolves with these social changes. In this respect, it is difficult to forecast the success or not of any evacuation. During a crisis period, misunderstanding and divergence of opinion will occur when collective decision prevails over individual decision.

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