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### ► To cite this version:

Jean-Claude Thouret, Emeline Wavelet, Marie Taillandier, Boedi Tjahjono, Susanna Jenkins, et al.. Defining population socio-economic characteristics, hazard knowledge and risk perception: The adaptive capacity to persistent volcanic threats from Semeru, Indonesia. *International Journal of Disaster Risk Reduction*, 2022, 77, pp.103064. 10.1016/j.ijdr.2022.103064 . hal-04047080

HAL Id: hal-04047080

<https://uca.hal.science/hal-04047080v1>

Submitted on 27 Mar 2023

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1 **Defining population socio-economic characteristics, hazard knowledge and risk**  
2 **perception to characterize the adaptive capacity to persistent volcanic threats from**  
3 **Semeru, Indonesia**

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19 *International Journal of Disaster Risk Reduction, 10 May 2022 Accepted*

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26 **ABSTRACT**

27 The densely populated and persistently active volcano of Semeru in East Java, Indonesia,  
28 hosts communities able to adjust to, compensate for, and tolerate continuous exposure to  
29 persistent volcanic threats. The goal of this research is to understand how, so that the  
30 knowledge can contribute to preparedness and support emergency management. We use  
31 surveys at the village scale and statistical analyses to explore the socioeconomic  
32 characteristics of communities with the aim to appraise how dense, rural/urban populations  
33 around a continuously active volcano can compensate for daily hardships and limited access  
34 to resources, which prevent post-eruption recovery. We found that sustainable, rural  
35 livelihood providing food and small-income jobs, diversified resources from ecological belts,  
36 new alternatives and temporary work migrations all compensate, while recurrent experiences  
37 on hazardous events may harness social adaptive capacity. What renders the majority of  
38 villagers around Semeru resilient to chronic threats lies in solidarity networks, cultural beliefs,  
39 trust in early warning and access to vital resources in case of crisis. Conservative, top-down  
40 risk management policies in Indonesia combined with obstacles that limit the adaptive  
41 capacity of communities results in disaster preparedness prior to large eruptions being too  
42 slow, with the subsequent management of the disaster likely to be inefficient. The  
43 conservative risk management policy likely suffices during periods of mild activity, but it  
44 may lead to future disasters in case of large eruptions or destructive lahars. The case study of  
45 population adaptive capacity thus provides a frame of reference for other disaster-prone  
46 countries.

47 **Keywords:** exposure; adaptive capacity; statistics; livelihood, volcano; Semeru

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50 **1. INTRODUCTION**

51 People have long settled around active volcanoes in tropical countries, especially in SE Asia  
52 (e.g., Merapi, Sinabung, and Mayon), where early dense populations and civilizations were  
53 supported by rice cultivation. What is less known is how communities thrive on persistently  
54 active volcanoes such as Semeru, and how they can incorporate the volcano's activity into  
55 their beliefs and culture. One interpretation is that villagers are able to adjust to the  
56 environment through a delicate balance between resources obtained from soil, land, a

57 diversity of jobs, beliefs, and cultural interactions with “Nature”. Such a balance helps the  
58 villagers to compensate daily exposure to economic and health hardships, and chronic natural  
59 threats: lahars, pyroclastic density currents (PDCs), tephra fallout, floods and earthquakes.

60 Previous studies evaluating how communities around persistently active volcanoes live with  
61 chronic volcanic hazards have used a combination of structured and semi-structured  
62 interviews (e.g., [Nobert et al. \(2020\)](#) for gas emissions from Masaya; [Naismith et al. \(2020\)](#)  
63 around Fuego), surveys (e.g., [Covey et al. \(2020\)](#) around Sakura-Jima; [Davis et al. \(2005\)](#)  
64 around Etna), both interviews and surveys ([Few et al. \(2017\)](#) for Tungurahua), participatory  
65 rural approaches (e.g., [Cronin et al. \(2004\)](#) for Ambae, Vanuatu), and analyses of oral  
66 traditions (e.g., [Cronin and Cashman \(2007\)](#)). Most studies have aimed to understand how the  
67 community response to future volcanic threats is shaped by their past experiences. For  
68 Indonesia, two notable works have sought to understand why dense populations thrive on  
69 persistently active volcanoes in Java ([Lavigne et al., 2008](#); [Bachri et al., 2015](#)). [Lavigne et al](#)  
70 [\(2008\)](#) studied how risk perception, cultural beliefs and socio-economic constraints shape the  
71 behaviour of Javanese populations facing volcanic threats around Merapi. A combination of  
72 socio-cultural factors (e.g., attachment to place, cultural belief) and socio-economic  
73 characteristics (e.g., standard of living, strength of people's livelihood, well-being) prompt or  
74 force people to live in and exploit areas at risk. In their study of the population living around  
75 the active Bromo cone in the touristic Tengger caldera, East Java, [Bachri et al. \(2015\)](#) raised a  
76 pivotal question based on a restricted survey: why do villagers choose to live with continued  
77 exposure to considerable hazard? Social capital, solidarity networks, and economy  
78 compensation were considered important to how people tolerate, compensate for, or accept  
79 the effects of chronic or persistent, deadly volcanic activity. However, both studies do not use  
80 detailed statistical investigation to support or analyse their findings. Here we develop  
81 multivariate analyses to detect relevant socio-economic characteristics and clustering  
82 techniques to distinguish groups of population before discussing factors of adaptive capacity.

### 83 **1.1. Objectives of the study**

84 The study is part of the ‘Local Adaptation to Volcanic Risk’ research project, which seeks to  
85 understand how densely populated villages continuously exposed to persistent volcanic  
86 threats can thrive on Semeru’s slopes and ring plain. Following the definition of a composite  
87 exposure index for villagers living on the volcano’s slopes ([Thouret et al., 2021](#)), this  
88 contribution aims at understanding how ‘intensive’ risk can be adjusted, compensated and

89 tolerated by mixed rural/urban populations exposed to hazardous volcanic environments.  
90 Intensive risk is associated with large concentrations of people and economic activities facing  
91 intense hazard events, which can lead to catastrophic impacts ([Barclay et al., 2015](#)), as shown  
92 by eruptions of Indonesia's chronically active volcanoes (e.g., Kelut, Merapi, Semeru).

93 With this survey-based approach to the Semeru case, and the statistical analysis of the  
94 datasets, we pursue three objectives (Figure 1):

95 1. To define the socio-demographic, economic characteristics and origin of mixed rural/urban  
96 population to assess the social vulnerability of Semeru's population.

97 2. To understand to which extent livelihood and local economic resources can compensate for  
98 the risk of living on continuously active volcanoes despite an exposure to a range of hazard  
99 zones.

100 By comparing livelihood and assets with socio-demographic characteristics, objectives 1 and  
101 2 help define socio-economic categories of population around Semeru.

102 3. To correlate the knowledge of hazards with levels of risk perception and associated  
103 variables at the individual scale to assess people's awareness and preparedness, thus  
104 appraising people's behaviour in case of imminent eruption and evacuation.

105 Our key hypothesis postulates that livelihood and resources of the population, established  
106 through local surveys at micro-economic level, will reflect the extent to which villagers are  
107 able to compensate for economic hardships and environmental constraints. The hypothesis is  
108 based on researchers' experience around Indonesia's active volcanoes (e.g., Merapi, Kelut,  
109 Bromo, Semeru; e.g., [Bachri et al., 2015](#)) and on wider literature on volcano hazards,  
110 exposure, vulnerability and risk (e.g., [Kelman & Mathers, 2008](#); see Section 1.3). Both  
111 experience and literature suggest that socio-economic characteristics and degrees of hazard  
112 knowledge and risk perception, together with associated variables (used elsewhere on active  
113 volcanoes), may enable us to appraise the awareness and preparedness of Semeru's population  
114 in case of evacuation forced by imminent eruptions. As the links between these concepts are  
115 not straightforward and remain descriptive, we tested their validity through a careful selection  
116 of variables and statistical techniques involving multivariate analyses and clustering.

117 The final goal of correlating household resources with population awareness/preparedness is  
118 to assess how different population categories cope with the adverse effects of the persistent

119 volcanic activity. We assess how Semeru's population compensates for the risk of living in  
120 areas affected by chronic lahars and daily eruptive activity by obtaining new alternative  
121 resources and incorporating both extensive and intensive risk into their culture, a process akin  
122 to adaptation to the potentially harmful environment. Our analytical approach on adjustment  
123 strategies and opportunities overcoming daily pitfalls and handicaps, narrows in from a  
124 national and regional scale (Indonesia, East Java, Semeru area) to a local scale (village and  
125 neighbourhood) in order to obtain several micro-economic criteria beyond macro-economic  
126 data from the literature. Results acquired on exposure, hazard knowledge, risk perception and  
127 associated variables, and preparedness around the volcano are significant when compared  
128 with studies of community response to volcanic crises. Such studies stem from Indonesia  
129 (cases of Merapi, Sinabung, Kelut: see [Andreastuti et al., 2019](#), Section 5.5), Papua New Guinea  
130 ([Torrence 2016, 2019](#)), Mt. Rainier, USA ([Wei and Lindell, 2017](#)), Tungurahua, Ecuador  
131 ([Few et al., 2017](#)), and at the broad scale of Latin America ([Nieto-Torres et al., 2021](#); [Freitas-  
132 Guimaraes et al., 2021](#)).

## 133 **1.2. The rationale for targeting communities around Semeru**

134 Semeru is Indonesia's highest volcano at 3676 m asl. located in East Java ([Fig. 2](#)). The  
135 volcano summit separates the Regencies of Lumajang to the East (1791 km<sup>2</sup>, 1,036,000  
136 people in 2015) and Malang to the West (3531 km<sup>2</sup>, 2,547,000 people) ([Table 1](#)). We focus on  
137 the regency of Lumajang where 621,000 people live within 35 km from the summit, and the  
138 SW flank where 317,000 people represent a quarter of the regency of Malang ([BPS, 2017](#)).  
139 Semeru is a real concern to civil authorities owing to the combination of daily explosive  
140 activity and a dense population: at least 950,000 people live within a radius of 35 km from the  
141 volcano summit. Lahar-related disasters caused >10,000 casualties during the 20th century  
142 alone. Semeru's 1909 catastrophic event ranks fourth among the ten deadliest eruptions in the  
143 world between 1900 and 2010, as the 1909 PDCs and lahars killed at least 5,500 people, i.e.,  
144 5.5% of all fatalities of the ten world's deadliest eruptions since 1900 ([Doocy, 2013](#)). These  
145 events created havoc in the ring plain where urban centres are currently thriving, in particular  
146 Pasirian, Tempeh, and Lumajang, harboring 123,000 people in 2015. The Semeru case hosts a  
147 range of areas exposed to deadly and/or disastrous pyroclastic density currents (PDCs) and  
148 tephra fallout on proximal slopes, lahars along valleys as far as 35 km, and a variety of  
149 exposed assets, such as crops, road network, lifelines, factories, trade centres, and religious  
150 edifices.

151 The East and South flanks and ring plain of the volcano are the most prone to volcanic  
152 hazards where 50,000 to 100,000 people are exposed to the effects of volcanic activity based  
153 on historical recorded eruptions and the hazard-zone map (Fig. 3). The hazard-zone map  
154 displays three areas most exposed to the effects of explosive activity and lahars (Thouret et  
155 al., 2007, 2014, 2021): 1) The high, steep cone and its flanks within a circle of 4-5 km radius  
156 are affected by tephra, lava flows and PDCs on the SE flank on daily to annual basis. 2) The  
157 extensive South, SE and ESE flanks affected by PDCs as far as 11-12 km and lahars as far as  
158 10 to 25 km from the vent, along which more than 50,000 people now live within 0.5 km of  
159 the active rivers. 3) The principal valleys draining the South K. (Kali= river) Glidik, K. Bang  
160 and K. Kembar), SE (K. Koboan), and East slopes (K. Tengah) convey pluri-annual lahars  
161 across the ring plain at least 35 km down valley to the Indian Ocean. This is the reason why  
162 we chose to conduct surveys along the valleys on the South, SE and East slopes most affected  
163 by PDCs and lahars in the recent past since 1909.

### 164 **1.3. Definitions: risk, vulnerability, adaptive capacity and resilience**

165 Risk can be measured as the product of probability  $\times$  losses, where the probability is a  
166 function of hazard and the losses depend on both exposure and external and internal  
167 vulnerability (Aspinall and Blong, 2015), comprising the capacity of a community to cope  
168 with the consequences of a disaster (UNDRR, 2017). The concept of risk considers hazard  
169 knowledge, risk perception and resilience among communities living on volcanoes (Chester,  
170 2005; Gaillard, 2007, 2008; Gaillard and Dibben, 2008; Paton et al., 2008; Lavigne et al.  
171 2008; Donovan, 2010; Donovan et al., 2018). A broader risk concept stems from the appraisal  
172 of value systems and beliefs, governance systems and decisions, and political economies  
173 (Bakkour et al., 2015; Donovan, 2019). A holistic approach to risk assessment thus  
174 encompasses all facets of human and volcano interactions, including sustainable livelihoods  
175 and strategies that enable people to adapt to, and thrive on, active volcanoes (Kelman and  
176 Mather, 2008; Few et al., 2017). Within the holistic approach, risk perception is not restricted  
177 to its affective response (e.g., feelings about a volcano), but it has the double dimension of  
178 perceived severity and perceived probability of occurrence. Here we consider the double  
179 dimension of risk perception together with a set of associated variables: the perceived risk  
180 salience, the hazard severity and likelihood, the sense of community and social capital, the  
181 place of attachment, the experience with the source of the risk (reflected by people's past  
182 behaviour and evacuation memory), the empowerment and self-confidence, the trust in

183 authorities and access to information, and the appraisal of governance in the mitigation  
184 domain (see section 3.3).

185 A definition of vulnerability (UNDRR, 2014) pinpoints ‘the conditions determined by  
186 physical, social, economic and environmental factors or processes, which increase the  
187 susceptibility of an individual, a community, assets or systems to the impacts of hazards’. We  
188 estimated social vulnerability by means of the SoVI index (Cutter et al., 2003) with its  
189 application to the Indonesia case (Siagian et al., 2013). The criteria of the SoVI index include:  
190 population number and density, annual growth rate, number of children under 5 years and  
191 elders > 65 years, literacy rate among adults, poor people, and HDI (Siagian et al., 2013).  
192 Most of these criteria around Semeru derive from the socio-demographic dataset (Survey A)  
193 (see section 3.1). The purpose of determining social vulnerability was to assess handicaps that  
194 prevent the population of surveyed dusun to cope with the impacts of volcanic hazards on  
195 livelihood and resources.

196 Adaptive capacity or coping capacity forms the background concept of the research project  
197 presented here. Adaptive capacity is “the combination of all the strength, attributes and  
198 resources available within an organization, community or society to manage and reduce  
199 disaster risk and strengthen resilience” (IPCC 2014; UN, 2016; UNDRR, 2017). The notion of  
200 adaptation to the environment involves the specific elements that allow a population to ensure  
201 the sustenance, and beyond, the autonomy of living and interacting with their chronically  
202 hostile environment. On volcano slopes, adaptation refers to changes in society that occur  
203 after an eruption and that increase future resilience by actively dampening or effectively  
204 mitigating the impacts of volcanic disasters (Torrence, 2019). Humans coexist with volcanoes  
205 exhibiting chronic activity, and so residing near a hazardous volcano does not mean that  
206 people cannot thrive on its slopes. Volcanoes are often interpreted by Indigenous people as  
207 entities that wreak vengeance to the world, bringing justice to life’s misgivings and  
208 wrongdoings of its inhabitants, but some religions and indigenous beliefs view volcanoes as  
209 part of Nature (UN-ISDR 2008). Many villagers living around SE Asia active volcanoes  
210 consider eruptions as agents of change and beneficial acts of creation and evolution (Dove,  
211 2007, 2008). Adaptation is thus a long-term and constantly unfolding process of learning,  
212 experimentation and structural / institutional changes that may reduce vulnerability (Birkman  
213 et al., 2013; Barclay et al., 2015).



214 Resilience and adaptation of groups or societies living around active volcanoes have been the  
215 focus of several studies following Chester's textbooks (1993, 2005). Previous studies on  
216 "adaptation to risk" refer to adjustment to losses (Chester, 2005): besides strategies for  
217 modifying the hazard and potential impacts, society can adjust to losses by spreading, bearing  
218 and planning for loss. Recent studies focus not only on adjustment to loss, but also to benefits  
219 drawn from the volcanic activity (e.g., de Bélizal, 2013). Diversity and transferability of a  
220 sustainable livelihood to other locations assist people in living with active volcanoes, as  
221 sustainable livelihoods usually enable communities to overcome the loss of assets and  
222 preserve the means to restore them, once the main shocks of eruptions have been absorbed.

223 Despite traditional similarities, resilience is not synonymous with adaptation (Jones, 2019).  
224 Lorenz (2013) has broadly defined resilience as the ability to maintain continuity by avoiding  
225 or withstanding failure (Lorenz, 2013). In the disaster research community, resilience is a  
226 term used to cover all actions that reduce losses from hazards, including mitigation (prior to  
227 disaster) and rapid recovery (post-disaster). These actions reflect how a community reduces  
228 the probability of structural or system failure prior to disaster, and how quickly it returns to  
229 normal in the aftermath of a disaster (Rose, 2004). Resilience can be used to describe the time  
230 it takes for recovery after an eruption, and/or the amount of disturbance required to shift  
231 livelihood regimes (Lorenz 2013), hence emphasizing the prominent role of change induced  
232 in a group or society by the aftermath of a disastrous eruption. Changes in society that occur  
233 after an eruption may increase future resilience by effectively mitigating the effects of  
234 subsequent volcanic disasters (Torrence, 2019).

235 Resilience is synonymous with sustainability as conservation of opportunities in most of the  
236 modern, econometry approaches (e.g., Koliou et al., 2018). Rose (2004) earlier defined static  
237 and dynamic resilience in the economy realm: static economic resilience refers to the ability  
238 or capacity of a system to absorb or cushion against damage or loss in a given period. A more  
239 general definition that incorporates dynamic considerations is the ability of a system to  
240 recover from a severe shock. Rose (2004) further distinguished two types of resilience: (1)  
241 inherent – ability under normal circumstances; and (2) adaptive – ability in a crisis situation  
242 due to ingenuity or extra effort. In the Semeru case, likewise in the aftermath of large  
243 eruptions, we will show that the adaptive capacity may prevail if the population exploits new  
244 alternatives to overcome daily hardships and limited access to resources (see Section 5).

245 Adaptation to change, as opposed to collapse (vulnerability) or stability (resilience), is  
246 considered as a potential consequence of exposure to extreme conditions. [Rose \(2004\)](#) posited  
247 that adaptation consists of two components: an active effect to reduce losses after an event has  
248 taken place (e.g., migration) and a passive absorption (“suffering”) of the loss. From historical  
249 accounts and archaeological findings among populations living in chronically exposed  
250 environments, Humans may be able to decrease their vulnerability and increase their  
251 resilience to extreme natural events (Torrence, 2016). Adaptation to the environment aims at  
252 defining how resilience comes into being and how it is being maintained, a process akin to  
253 adaptive capacity. This concept is close to sustainability that is the economic and social  
254 resilience integrated with environmental threats and opportunities offered by resources on a  
255 volcano and intrinsic capacities of communities to shift livelihood and life habits. The key  
256 variables for resilience relate to robustness of the population (e.g., health, social capital) and  
257 available resources as well as the nature of available options ([Tobin and Whiteford, 2002](#);  
258 [Torrence, 2019](#)). Recently, [Nieto-Torres et al. \(2021\)](#) used 12 parameters to quantify  
259 resilience in the framework of their new inclusive volcanic risk ranking. He authors defined  
260 and scored these parameters, ranked under mitigation procedure and response to eruption, in  
261 addition to a large set of hazard, exposure and vulnerability parameters, and applied them all  
262 to volcanoes in Mexico. Subsequently, [Freitas Guimarães et al. \(2021\)](#) used this set of 12  
263 parameters to rank volcanic risk (VRR) around 123 active volcanoes in Latin America.  
264 Although vulnerability significantly contributes to the VRR score, hazard and exposure are  
265 the main factors that define the risk of Latin American volcanic systems in the proposed 3-  
266 factor VRR, while resilience contributes to its reduction in the proposed 4-factor VRR  
267 strategy.

268 We investigated vulnerability and adaptive capacity together for the sake of appraisal of the  
269 driving factors. In their review of concepts and measurements of vulnerability and resilience,  
270 [Noy and Yonson \(2018\)](#) argued that apart from the characteristics of the hazards, the potential  
271 for people and economies to avoid adverse impacts and their capacity to withstand and  
272 rebound from a disaster may be shaped by a confluence of socio-economic factors. These  
273 factors derive from macro-economic criteria, such as gross domestic product (GDP) or  
274 regional production, income, employment, inflation, consumption, expenditures, savings,  
275 domestic and international financial transfers, public finance, and trade income per capita,  
276 poverty status of households, and the share of income of alternative sources of income.  
277 However, socio-economic factors also derive from micro-economic criteria at a local scale.

278 Such criteria and scale substantiate the motivation of this study conducted on the populations  
279 living in at-risk environment around Semeru. Among the criteria, we identify the small  
280 number of working age members, those households with a large number of members, the high  
281 rate of informal workers, and the ethnic minority groups such as the Maduranese; limited  
282 access to financial aid; children dropping out from school, and the paucity in household  
283 expenditures on medicine and nutritious foods.

## 284 **2. METHODS AND DATA ACQUISITION**

285 Local-scale surveys of *dusuns* and neighbourhoods (hereafter termed blocks) around Semeru,  
286 are more adapted than the country scale to describe the characteristics of dwellers exposed to  
287 considerable hazards. A local scale has the advantage to encompass: (1) the mixed rural and  
288 small urban communities; (2) a variety of activities, resources, and habitat, which support  
289 livelihoods and sustain the population, and (3) social capital, traditional beliefs, and risk  
290 culture involved in preparedness to face volcanic crises.

### 291 **2.1. Data acquisition and targets**

292 The number of surveys collected during two field campaigns in September 2018 and 2019  
293 allowed us to distinguish socio-economic categories among the population in rural villages  
294 and small towns as well as categories of buildings, which we ranked according to their  
295 structural typology and physical vulnerability (ESD Tables 1, 2). We collected data on  
296 demographics, economic activity (agriculture, animal husbandry and agroforestry) and  
297 mitigation policy from eight governmental offices in: *Desa* (sub-district) Tamansatryan  
298 (WSW flank), *Desa* and *Kecamatan* (district) Pronojiwo (South), *Desa* Oro-oro Ombo and  
299 Supit Urang (SSE), *Kecamatan* Candipuro and *Desa* Sumberwuluh (SE), *Desa* Pasrujambe,  
300 and *Desa* Senduro (East) (Table 1, Fig. 2). We selected 13 *dusuns* and 2 small towns that  
301 belong to six *Desa* on the SW, S and E slopes of Semeru inside four *Kecamatan* in the  
302 Regency of Lumajang and one in that of Malang (Table 1, Fig. 2; ESD Fig. 1). A Trimble TC  
303 1000 GIS mapper device, Google Earth Pro maps and topographic maps (scale 1:25,000) have  
304 been used in QGIS to locate the building stock and survey sites and collate structural  
305 observations on homes, government offices, schools, health centres, mosques, and markets  
306 (Fig. 3, ESD Fig. 1). We have outlined on Google Earth maps the boundaries of *dusuns* and  
307 blocks in the vicinity and outside the active valleys that convey lahars or PDCs (Fig. 3, ESD  
308 Fig. 1).

309 The SE, East and NE slopes of Semeru were the target of two field campaigns in September  
310 2018 and 2019. Together with Indonesian partners from University Gadjah Mada and Institut  
311 Pertanian Bogor, we chose dense, mostly rural *dusuns* (sub-villages) located in the most  
312 exposed areas between 8 and 20 km from the volcano summit on the basis of past eruptions  
313 and reported fatalities since 1884 (Thouret et al., 2007, 2021). The primary target was  
314 neighbourhoods located on the valley margins, terraces and interfluves within 0.2 and 1 km  
315 from the active channel that were affected by lahars and PDCs in the recent past. These  
316 neighbourhoods are located in the vicinity of K. Bang, K. Kembar (e.g., 2002-2003) on the  
317 South flank, K. Koboan and Curah Lengkong (1994-1995, 2020-2021) on the SSE flank, K.  
318 Tengah (1981) on the East slope, and in the SE and East ring plain (K. Rejali, Mujur) towards  
319 the city of Lumajang, affected in 1909. We selected the remaining *dusuns* within the reach of  
320 light ashfall for the purpose of comparison as they extend outside of valleys (e.g., Pasrujambe,  
321 Fig. 2) and farther away from the volcano. We included small rural *dusuns* at higher altitude  
322 on the west flank that are exposed to frequent tephra-fall within the 9 km circle distance from  
323 the crater (Fig. 3). Almost 77% of the respondents live in *dusun*, while 23% of them live in  
324 small towns (ESD Table 1). We consider mixed rural/urban population in two towns:  
325 Pronojiwo close to the active K. Bang and Kembar valleys, and the least exposed Senduro  
326 farther away (17 km) from the volcano and 2 km from the active K. Tengah (Fig. 3).

## 327 2.2. Surveys, respondents, and context

328 We collected survey information in the field across 15 *dusuns* and within 145 blocks (Fig. 2,  
329 ESD Fig. 1). We collected data from 2 to 4 households per *RukunTetanga* (RT, 20-25 homes),  
330 the smallest administrative unit at which respondents can be identified. Three to five RT  
331 typically form a *RukunWarga* (RW, a set of 50-75 buildings, mostly homes with a few  
332 offices, shops, mosques and schools). We conducted five face-to-face interviews per  
333 household in Indonesian and/or Javanese language thanks to our partners. The five surveys  
334 conducted in one sitting per household dealt with socio-demographic characteristics (Survey  
335 A), hazard knowledge (B), risk perception and associated variables (C+D2), household  
336 resources (D1), and building stock (E). As a result, 1,255 surveys were conducted,  
337 encompassing 279 respondents from 221 households, which host as many as 1,161 persons  
338 (Table 1). ESD Text displays the list of survey topics and questions.

339 Interviews and informal chats offered pivotal sources of information, combined with a warm  
340 hospitality from many respondents who provided insightful comments on their experience,

341 culture and community life. We invited respondents upon the availability of persons in the  
342 household, either male or female, through a random door-to-door approach and with the  
343 interpreter's help. A very few people of Madura origin were excluded from surveys if they did  
344 not speak Indonesian or Javanese. Informed consent was obtained by the interpreter  
345 (Indonesian and Javanese language) prior to the interviews. The proportion between gender  
346 and age groups among respondents is balanced, although children attended school at the time  
347 of the interviews. A small number (2%) of children above 7 years old were surveyed in two  
348 schools, together with their teachers. A small number of respondents ( $\leq 6\%$ ) did not provide  
349 answers to several questions due to time limitations, lack of knowledge (e.g., a few elder, very  
350 low-income, minimally educated or disabled people), and a mixture of shyness, safety  
351 concern, and/or interfering concerns during interviews. Up to 11% of respondents provided no  
352 answer to questions implying memory, illustrating that the footprint of many volcanic events  
353 (except the largest disasters) may be erased after 15-20 years. Another reason is that 20% of  
354 people arrived less than 25 years ago in the Semeru's area, and therefore did not experience  
355 severe impacts from volcanic activity.

356 Surveys involving about 1,200 people and 300 buildings represent approximately 0.6% to  
357 2.6% of the respective cohorts. However, field observations, completed by data extracted  
358 from *Kecamatan* reports and 2017 BPS census, involved 145 blocks from 15 *dusuns*, hence  
359 representing 3% to 6% of exposed people. The results presented here provide a socio-  
360 economic picture as of 2018-2019, but an economic recession hit Indonesia and worldwide  
361 alike in 2020. The most recent eruption (December 2020-January 2021) likely modified some  
362 results as well.

### 363 **2.3. Statistical analysis procedure**

364 To achieve the objectives listed in section 1.1, we explored and coded the answers extracted  
365 from five surveys to run statistical methods on a large collection of suitable variables, which  
366 allowed us to examine the characteristics of the population exposed to volcanic threats. We  
367 conducted statistical investigation using the R software and involved two main strategies. The  
368 first, using univariate and multivariate analyses, intended to explore data and extract relevant  
369 variables. The second strategy was rather oriented toward detection of relevant variables and  
370 identification of population groups based on one clustering technique. Data analysis involved  
371 three statistical techniques ([Table 2; Chambers et al., 2018](#)):

372 1. Univariate analysis (UA), which is useful for exploring the dataset and computing the  
373 frequency of each of the categories of all variables.

374 2. Multiple Correspondence Analysis (MCA): a data analysis technique used to detect and  
375 represent underlying structures in a large set of categorical data (Abdi and Valentin, 2007).  
376 This technique represents data as points in a low-dimensional Euclidean space, illustrated by  
377 biplots with two dimensions (e.g., ESD Fig. 2). We use results from the MCA conducted on  
378 81 variable categories stemming from five survey datasets (Table 2 and ESD Fig. 2). The  
379 MCA results help quantify the qualitative survey data with the aim to distinguish population  
380 groups by means of clustering techniques (see below). We selected the number of dimensions  
381 taking into account the MCA results (ESD Fig. 3), a scree plot showing eigenvalues following  
382 the Benzécri correction. Then we focus on the first 11 dimensions, which retain 81% of the  
383 information, and we present the contributive variables more correlated to the dimensions.

384 3. Statistical detection leading to elaboration of categories was based on Hierarchical  
385 Agglomerative Clustering (HAC), which included the following three steps:

386 First, HAC has been performed on the MCA outputs with the purpose to convert qualitative  
387 variables into quantitative variables and to construct groups of observations (population  
388 groups) sharing the same statistical characteristics. Each of the clusters should be as different  
389 from one another as possible. Each grouping was made according to the distance matrix  
390 (showing distance between each group; a distance of zero suggesting two observations were  
391 identical), two at a time, until clusters were obtained.

392 Second, a Chi-square test has measured the link between the set of variable categories and a  
393 cluster (that is the variable of interest), in order to select a small number of categories that  
394 help discriminate clusters with a p-value  $< 0.05$  (See Section 4). We ranked the selected  
395 variables from the smallest p-value (i.e., more discriminant) to the p-value as close as to 0.05  
396 (i.e., less discriminant).

397 Third, a biplot (ESD Fig. 2) shows that the majority of variables correlated with dimensions 1  
398 and 2 are also the most discriminant. These are also the first variables from the Chi-squared  
399 test. Barplots highlight the fifteen most contributive categories along dimensions 1 and 2 that  
400 retain at least 37% of the information (ESD Figs. 2A, B, and 4).

401

### 402 3. RESULTS: CHARACTERISTICS OF AT-RISK VILLAGERS

403 We conducted statistical analyses on five survey datasets: socio-demographics, hazard  
404 knowledge, risk perception and associated variables / awareness, and livelihood and  
405 resources, including homes and belongings. The ultimate goal of our statistical investigation  
406 was to assess how these characteristics help villagers to adjust to the effects of persistent  
407 volcanic threats from Semeru.

#### 408 3.1. Socio-demographic characteristics and geographical origin of the population

409 Seven characteristics stem from Survey A (List of questions, [EDS text 1](#)): (1) Gender, age  
410 group, and marital status; (2) Household composition and age groups; (3) Education level; (4)  
411 Socio-professional categories; (5) Number of contributory persons and monthly income; (6)  
412 Geographical origins of respondents, parents and grand-parents, and (7) Time living in the  
413 area and ancestor arrival time.

414 [Table 3](#) summarises the survey results based on frequency analysis from 279 respondent  
415 interviews, allowing us to distinguish five socio-demographic groups A-E among the *dusuns*.

416 Two groups A and E prevail at both ends of the socioeconomic spectrum.

417 Group A: Almost 35% of our respondents were young and mature adults who are financially  
418 independent, relatively educated (secondary school), and contribute to the household income.  
419 Most respondents were born around Semeru or came from East Java several decades ago.

420 Groups B and C are similar in origin (Semeru or the rest of Java), but show contrasted  
421 resources. Group B, representing almost 6% of our respondents, includes young people, adults  
422 and elderly, educated or not, but financially independent and benefiting from resources,  
423 whereas Group C represents 16% of respondents and includes youngsters or young adults,  
424 educated but without or with only low resources.

425 Group D: The least represented group (<3%) includes adults and older persons, educated but  
426 also dependent on families, and either local or from beyond East Java origin.

427 Group E: More than 40% of our respondents were mature adults and elderly, minimally  
428 educated, without or with only low resources and therefore dependent on families, who were  
429 born in the area or arrived < 25 years ago from Madura or beyond East Java. This cohort  
430 appears to be the most socially vulnerable, to whom we may add groups C and D (19%) who  
431 are relatively vulnerable.

432 A detailed account of socio-demographic findings from Survey A, compared to nationwide  
433 and Java data ([Siagian et al., 2013](#); [BPS, 2017](#); [Nasution et al., 2020](#)), is provided in [ESD](#)

434 [Text 2](#) and illustrated in [Fig. 4](#) and [ESD Fig. 5](#). We identified three parameters that may  
435 diminish the adaptive capacity to chronic risk: 1. The proportion of children <14 years (24%)  
436 is comparable nationwide (26%), while the proportion of elderly people >60 years (12%) is  
437 double that of Indonesia (6.10%) ([Fig. 4](#); [ESD Fig. 5, graphs ‘g’1-4](#)). 2. Illiterate villagers  
438 (10%) around Semeru exceed the proportion nationwide (4%), while only 5% around Semeru  
439 have attended university, compared to 11% nationwide ([ESD Fig. 5, g5](#)). Minimal education  
440 contributes to relatively high social vulnerability around Semeru in particular in Lumajang  
441 regency, compared to moderate rates across most of Java ([Siagian et al., 2013](#); [Nasution et al.,](#)  
442 [2020](#)). 3. Informal workforce (about 70%), a source of economic inequality, prevail in *dusun*  
443 and small towns, higher than 58% nationwide ([Fig. 4](#)). Most women are housewives, but  
444 many own one small shop in c. 15% of the *dusun* houses, compared to 4.5% nationwide.  
445 [Nasution et al. \(2020\)](#) used 15 parameters to compute their Social Vulnerability Index at the  
446 regency level across Indonesia. From their Figure 4, the regency of Lumajang has a high  
447 social vulnerability based on three main parameters: low education, lack of disaster training,  
448 and disaster-prone area.

449 Knowing the origin of the population living on Semeru’s slopes and the ancestor arrival time  
450 allows us to gauge whether long experience in at-risk areas or attachment to place has enabled  
451 people to tolerate persistent volcanic threats. Almost half (47%) of the respondents were born  
452 around Semeru, but this proportion increases to c. 56% if we also consider East Java for  
453 birthplace ([ESD Fig. 5, g7](#)). However, Madura, an Island 105 km from Semeru, North of  
454 Surabaya, is the second origin for over one third of the respondents. Supporting this trend, a  
455 substantial 22% of the villagers migrated here from other provinces of Java and Madura over  
456 the past 25 years, often with limited knowledge of volcanic threats. A majority (53%) of the  
457 respondents have been living on Semeru volcano between 25 to 50 years, while c. 26% of  
458 them resided more than 50 years mostly in the same village ([ESD Fig. 5, g14-15](#)).

### 459 **3.2. Gauging volcanic hazard knowledge amongst villagers**

460 We asked thirteen questions around five themes in the framework of Survey B ([EDS Text 1](#)):  
461 (1) volcano name and most recent eruption, (2) Semeru’s hazard-zone map, (3) three most  
462 frequent volcanic threats in the area, (4) lahar occurrence and timing, and (5) eruption  
463 duration and lahar arrival time. [Table 4](#) distinguishes four levels of knowledge among the  
464 villagers, based on frequency analysis:



- 465 1. A third of the respondents (c. 33%) showed a fair knowledge of hazards, except PDCs that  
466 they did not experience. Fair knowledge of those living away from rivers relied on indirect  
467 experience, TV reports, or words of mouth with relatives or neighbours.
- 468 2. Almost a quarter of our respondents (c. 23%) showed a very good knowledge of Semeru's  
469 hazards, in particular a genuine understanding of lahar behaviour and effects. Such knowledge  
470 is rooted in direct experience for those living near active rivers and in higher education among  
471 teachers, the staff of health centres and disaster risk agency, and local authorities.
- 472 3. Over a quarter of respondents (c. 28%) had a regular or limited knowledge of hazards. They  
473 become easily confused when facing specific questions about hazards, including lahars  
474 despite their frequent occurrence, and correspond to those with a minimal education level.
- 475 4. A small number of people (c. 17%) had no knowledge of hazards and were unaware of  
476 environmental issues; either because they had not been educated, or suffered from disabilities  
477 and poverty that prevented them attending school. Migrants who arrived only a few years ago  
478 from non-active volcanic areas without a direct view on the active volcano remain essentially  
479 unaware of hazards.

480 [ESD Text 2](#) and [ESD Figure 6](#) show results from Survey B related to hazard knowledge. To  
481 sum up: 1) Basic knowledge about Semeru is widely shared, with almost 89% of the  
482 respondents identifying their closest volcano and two-thirds the year of its last eruption ([ESD](#)  
483 [Fig. 6, g1-2](#)). 2) The official hazard-zone map ([Bronto et al., 1969](#)) was shown to all  
484 respondents with the aim of evaluating to which extent volcanic hazards and colour-coded  
485 hazard zones were understood, and whether the map was used as a communication tool for  
486 villagers near active valleys. The majority of respondents (c. 55%) cannot read the hazard-  
487 zone map, which is not displayed in schools ([ESD Fig. 6, g3-5](#)). Knowledge is insufficient  
488 based on education, as basic elements of eruptive activity, volcanic hazards and impacts are  
489 not taught across East Java. Communication on hazard-zones appears to have been poorly  
490 disseminated and the relatively poor understanding of hazard zones does not match the  
491 purpose of the disaster risk management agency (BNPB) to promote awareness amongst  
492 exposed dwellers. 3) Knowledge on the principal hazardous volcanic phenomena (ashfall,  
493 PDC and lahar) is contrasted ([ESD Fig. 6, g6](#)). As many as 75% know what ash is, but at least  
494 36% of the villagers do not know how deadly PDCs can be. In contrast, c. 85% of people  
495 know lahars and a large majority are able to distinguish hot or cold lahars and *banjirs*  
496 (Indonesian term for hyperconcentrated flow), and how they can be triggered. 4) Knowledge  
497 on lahars is widespread, as almost 50% of people know, at least approximately, lahar

498 occurrence and frequency (ESD Fig. 6, g7-9). However, 42% of the respondents cannot  
499 estimate the arrival time of a lahar near their village, hence how much time they would have  
500 to escape from the most frequent threat once early warning had been emitted. 5) Knowledge  
501 on Semeru's eruptive activity is equally fair as 71% of the respondents estimate that an  
502 eruption can last hours to days. Almost 44% of them answer that lahars can be produced  
503 within hours after an eruption (ESD Fig. 6, g10-11).

### 504 **3.3. Evaluating risk perception and associated variables amongst villagers**

505 The first goal of Surveys C+D2 (34 questions, ESD Texts 1, 2) was to evaluate how villagers  
506 perceive volcanic risk from Semeru and compare the perception with hazard knowledge. The  
507 second objective was to assess to which extent villagers would be prepared for evacuation  
508 prior to an imminent eruptive crisis. Despite some biases and a complex dataset to interpret,  
509 four contrasted groups of population (termed r for risk) stem from Surveys C+D2 (Table 5):

510 The first group Ar (c. 24-26%) is aware, self-confident, and feels empowered for several  
511 reasons: they have lived in the area for >50 years and are well prepared for an eruption, which  
512 has deep roots in education, experience (having suffered from several evacuations) and local  
513 solidarity networks.

514 The second group Br gathers more persons (c. 29-30%) who are more concerned about daily  
515 life hardships, feel less empowered when facing hazardous events, but remain self-confident.  
516 These low-income people are more concerned about daily life than volcanic threats and may  
517 be less prepared, as they check early warning messages from government agencies with other  
518 sources.

519 The third group Cr has a similar proportion (c. 26-26.5%) of people concerned about the  
520 volcano to B, who feel a bit insecure and are wavering in case of crisis. This group of  
521 respondents typically have low-income jobs and are less educated, without interest in  
522 watching lahars, leading to them feeling more vulnerable. Some of them suffered from  
523 eruptions and/or accidents akin to trauma involving family or friends.

524 The least numerous group Dr (c. 19-21.5%), is unaware, distrustful, and are poorly prepared  
525 to abide by evacuation orders. They correspond to the very low-income, old or disabled  
526 cohort, with minimal education and poor knowledge on volcanic hazards. They do not  
527 participate in solidarity networks or associations and do not trust anyone upon warning. Such  
528 finding has a strong implication in terms of mitigation policy and dialogue from the officials  
529 (see section 5.6).

530 Questions asked under nine themes and based on concepts of social science (e.g., Johnston et  
531 al., 1999; Paton, 2003; Davis et al., 2005; Haynes et al., 2008a), aimed to define risk  
532 perception and associated variables, awareness and preparedness, as shown in Table 5 and  
533 illustrated in ESD Figure 7 A, B. These concepts include hazard salience, sense of community  
534 and social capital, hazard likelihood and severity, past behaviour and memory, self-  
535 confidence, empowerment, trust in authorities, appraisal of risk mitigation governance, and  
536 personal feelings. The replies to these questions provide key issues to appraise to which extent  
537 population may weigh in volcano risk against daily risks around Semeru.

538 1. Hazard salience (Davis et al., 2005) does not prevail here. The active volcano is a concern  
539 shared by more than 49% of the respondents, but daily hardships are more widespread and  
540 pervasive concerns (ESD Fig. 7A, g1-3). Questions asked about the Semeru's dangerous  
541 activity raised ambiguous answers: the volcano, a protecting feature in dwellers' home  
542 backyard, does not seem to be a major concern, although 32% feel worried by potential  
543 impacts of eruptions and an equal proportion by lahars.

544 2. Adaptation to risk relies on the sense of community and social capital (ESD Fig. 7A, g4-6).  
545 Villagers participate in solidarity jobs almost daily for the benefit of the group: not only 91%  
546 in *kerja bakti* (community service) or *gotong royong* (cooperation in daily life and work, and  
547 mutual help in case of disaster), but also in other cultural, religious or sport organization.

548 3. Most people do not perceive well the likelihood and severity of lahars and PDCs (ESD Fig.  
549 7A, g7-9). Almost 65% and 58% of respondents do not believe that lahars or PDCs,  
550 respectively, would hit them again. A reassuring fact, however, is that more than 26% of the  
551 respondents are aware that PDCs and lahars might hit them in the future.

552 4. Almost 89% of respondents feel that they acquired experience with volcanic threats,  
553 directly for almost 46%, vicariously for 23% or indirectly for  $\geq 20\%$  of them (ESD Fig. 7A,  
554 g10-12). A large majority of respondents believe that their estimate on lahar and PDC  
555 hazardous effects has been acquired from, firstly experience for 54%, secondly school and  
556 authorities for 22%, and thirdly from families and neighbours (g15-17).

557 5. Past behaviour, memory and self-confidence do not play a full role on the decision to  
558 evacuate. Among one third of the villagers who has been evacuated at least once, 28% did not  
559 check their decision with anyone, but as much as 43% searched for advice and, a noteworthy  
560 c. 12% did not know what to do (ESD Fig. 7B g20-22). These results show that two thirds of  
561 villagers have not been evacuated or did not remember the evacuation. Among the evacuees,

562 past experiences of unwise behaviour and/or poor memory of previous evacuations did not  
563 lead to improved future behaviour (i.e. the evacuees did not draw on these past experiences);  
564 rather, they reported that they would keep searching for advice or remain inactive, despite  
565 early warning messages of imminent eruption.

566 6. Villagers' empowerment or self-confidence is low, as almost 54% correctly think that the  
567 flows are too powerful to be overcome, but 36% of them admit that overcoming the impacts  
568 of the flows is also difficult or impossible (ESD Fig. 7B g23-25). When facing an eruption or  
569 a crisis, villagers' empowerment reaches low level (> 43% of them feel little self-confidence),  
570 whereas 18% only feel empowered or confident enough to escape from flows (g26).

571 7. Trust in official early warning messages and accurate information about imminent  
572 eruptions are two major issues for evacuation policy (Haynes et al., 2008b). Almost two thirds  
573 (65%) of villagers declare that they will abide by the evacuation order, but 7.5% affirm that  
574 they will never obey, and as much as 12% do not trust anyone (ESD Fig. 7B g27-31). Trust in  
575 government agencies has basis on personal experience during past evacuations and  
576 widespread respect for the authorities in Indonesia. There is room for improving information  
577 about mitigation policy and risk communication, as a non-negligible part of the villagers do  
578 not trust anyone (12%), do not answer (14%) or misunderstand the question (5%).

579 8. Overall, people appreciate government actions that promote preparedness for natural  
580 disaster, although such appreciation is a sensitive subject and many answers may therefore be  
581 biased. The positive appreciation steadily increases from 41-48% at nation and region scale to  
582 58% at local scale (ESD Fig. 7B, 32). Up to 20% of the respondents declare that the  
583 governance should be improved in terms of mitigation nationwide and regionally, but they  
584 seem less skeptical about the local administration. This suggests that the mixed judgment of  
585 the actions promoting preparedness at national level may be due to recent examples of poor  
586 crisis management elsewhere in Indonesia, such as the 2018 Pulu tsunami aftermath in  
587 Sulawesi, an example the respondents bore in mind at the time of interviews.

588 9. Ranking personal feelings about volcano, lahar and PDC hazards is akin to affective  
589 responses (Wei and Lindell, 2017). Villagers living on Semeru's slopes are not afraid of the  
590 eruptive activity or lahars, probably due to a long, shared experience: at least 44% of them  
591 argue that they feel "calm". A limited <20% of people boast about being calm in case of PDC  
592 events, but more than 52% of the respondents are afraid and over 19% concerned about PDCs.

### 593 **3.4. Economic status: household resources and building stock**

594 Household resources and economic status are tools to understand to what extent family  
595 livelihood and assets help people tolerating exposure to persistent volcanic threats. Here,  
596 livelihood means resources that a household avail from a diversity of crops, plantations or  
597 agroforestry, small-income business and trade money inside and outside the villages.

### 598 **3.4.1. Assets, livelihood, evacuation facilities and handicaps**

599 Questions on both tangible and intangible assets were asked (EDS Text 1, Survey D1) in each  
600 household (Table 6, ESD Fig. 8A, B) to estimate how people may balance daily risk with  
601 benefits from available resources. ESD Text 2 and ESD Fig. 8 show the following results:

602 1. The first asset concerns home, land and trade. Almost 90% of the respondents own their  
603 homes (ESD Fig. 8A, g1-3). Small land agricultural economy prevails, smaller than one acre  
604 (0.4 ha). Almost 78% of the villagers own a small garden, but a minority of them possess a  
605 sizeable piece (1 ha) of land, rice field or plantation, the property being smaller (0.2-0.5 ha)  
606 for trees and fruits. Half of the respondents cultivate and harvest one particular crop, but  
607 another half of farmers tends at least two crops (ESD Fig. 8A, g4). Widespread trade in  
608 Javanese rural communities includes a dense network of shops in *dusun* and markets in Desa  
609 (ESD Fig. 8A, g6). Hence, a small amount (c. 8%) of households appears to be landlocked  
610 and self-sufficient.

611 2. Household tangible assets are twofold (ESD Fig. 8A, g7). 1) Home belongings are  
612 contrasted: an overwhelming majority of people (c. 90%) own at least one motorbike and one  
613 TV, but a small number of electronic appliances and cars. 2) Animals represent a pivotal asset  
614 in rural Javanese communities.

615 3. The household livelihood, third asset, determines the measure of available resources.  
616 Livelihood consists of informal activities for 55%, small businesses for 33%, while public  
617 jobs occupy a mere 11% (ESD Fig. 8A, g8). About 74% of households receive earning from  
618 one or two family members (g9). A limited number (10%) of households suffer from very low  
619 income, close to the Indonesia average (9.8%) as of 2017 (Fig. 4). Financial issues represent a  
620 sensitive subject, so biases may largely impair replies to questions related to household  
621 income, insurance and loans. Nevertheless, 46% admit that they are indebted to banks and  
622 over 33% resort to microloans, but an overwhelmingly 73% are not insured against any kind  
623 of loss (Fig.4; ESD Fig. 8B, g11-13).

624 3. The fourth asset considers evacuation facilities and experience in case of volcanic crisis.

625 Over 73% of respondents declare that access to evacuation facilities is good to very good, but

626 61% of people consider themselves without protection works against the effects of volcanic  
627 flows (ESD Fig. 8B, g15, 16). More than one quarter of the surveyed villagers was evacuated  
628 at least once in 2002-2003, and older persons in 1994-95 or 1981 due to large eruptions and  
629 voluminous lahars (see Fig. 7B-21). More worrying, 41% of the respondents suffer at least  
630 one handicap, either physical, economical or psychological, which may prevent them from  
631 accessing shelters in case of evacuations (ESD Fig. 8B, g17).

### 632 **3.4.2. Regular to moderate vulnerability of the building stock**

633 The building stock is one of the major assets that we use to analyse economic resources and  
634 vulnerability at the scale of the *dusun* blocks and small towns (ESD Table 1). We measured  
635 11 parameters of building performance (Survey E, ESD Table 2) with the aim to assess the  
636 exposure and physical vulnerability of the building stock with respect to the potential impacts  
637 of lahars, PDCs and tephra fallout load. The structural typology includes seven classes (ESD  
638 Fig. 8B, graph 18, ESD Table 3) in which regular (3A: 47%) and average (3B: 33%) types  
639 prevail, totaling almost 80% of the stock: these are typical, single-storey, Javanese rural  
640 houses with a pitched roof, cheap masonry, and thin timber. The remaining stock include c.  
641 29% of high quality, expensive buildings, c. 6% of low-quality houses, and c. 6% shanty  
642 homes. Most of the houses were built without qualified contractors, except for scarce, high-  
643 rise buildings in towns.

644 Four vulnerability classes (A0, A, B and C) of homes and official buildings (schools,  
645 administration offices, health centres) were used to describe resistance to volcanic impacts  
646 (ESD Fig. 8B, g19): tephra-fall load on roofs, dynamic pressure of PDCs and lahars on walls  
647 and openings. Structural type 1 is the lowest resistant A0 (6%), type 2 is low resistant A  
648 (33%), types 3A and 3B are regular B (47%), while types 4 and 5 are resistant C (7% each).  
649 The regular B vulnerability of almost half of the building stock implies a moderate resistance  
650 to volcanic threats, weaker in case of fast-moving PDC and lahars with strong (> 25 MPa)  
651 dynamic pressure. Impact forces in turn were estimated from the quality of construction  
652 material and design (e.g., Thouret et al., 2020). The very small percentage (6%) of class A0-  
653 houses would not withstand either tephra fall, PDCs, or lahar effects. The A-house class  
654 would withstand thin, dry ashfall (< 10 cm) only, but would not bear PDC heat and pressure.  
655 A majority of houses contain wood walls and timber flammable in contact with hot PDCs,  
656 including ash-cloud surges far away from the valleys. Tile or zinc roofs supported by wood  
657 timber are not resistant to tephra load if ashfall thickness exceeds 25 cm combined with high

658 moisture content, but the large majority of pitched roof covered by tiles may help ash-  
659 cleaning operations up to about 25 cm in thickness. A small number of buildings (<7%)  
660 shows better resistance to impacts: large, 2+ storeys, masonry houses with four-sided pitched  
661 roofs, supported by strong wood and metal timber, while large traditional administration  
662 buildings would not collapse under thick and dry tephra-fall deposit.

### 663 **3.4.3. Socio-economic categorization of households**

664 We distinguish four types of households based on socio-professional categories, resources,  
665 livelihood, access to facilities, financial-insurance status, and habitat. Potential biases may  
666 affect the quality of survey results, and the sample may not be representative of all households  
667 around Semeru, as benefits or cut offs in trade, transport, agriculture and industry outputs  
668 should be incorporated. Financial data are poorly accessible, and 15 to 25% of villagers only  
669 possess bank accounts or insurance contracts. Despite all biases, [Table 6](#) summarizes four  
670 socio-economic types of households:

- 671 1. Low-income households amount to almost 44%, which host workers with two small-  
672 income jobs, one in traditional agriculture and another in temporary material extraction from  
673 rivers or in house/road construction. Small shopkeepers in *dusun*, mostly housewives, and  
674 school teachers are added. Other characteristics include two contributory persons below the  
675 average wage threshold; a small number of small cattle; little savings and/or insurance  
676 coverage, and; modest houses B or C (about 2,150 US\$). Traditional households own micro  
677 arable land (<500 m<sup>2</sup>), a garden and poultry.
- 678 2. The middle-income households (c. 29%) benefit from a diverse livelihood and combined  
679 incomes from 2 to 3 people that support two families, including high school teachers, health  
680 staff, high-ranked civil servants, wood or food factory owners, shop retailers, and harvest  
681 collectors or small land owners. They own two or more motorbikes, sometimes one car or a  
682 small truck, TV and at least one electronic appliance. They own large, well-maintained houses  
683 C, sometimes including a shop (about 2,100 to 3,600 US\$).
- 684 3. Very low-income households (c. 22%) include laborers without land, employees in small  
685 business, street retailers, and elderly or disabled people. One member only brings income to  
686 household below the national IDR threshold. They own very modest or modest type A or B  
687 homes, small livestock, without electronic appliances (only TV) and motorbike. They avail no

688 savings or insurance, while the health coverage is limited to elderly and lowest-income  
689 people.

690 4. Scarce (<6%) high-income households host several people with multiple jobs: trade  
691 business, construction, wood and food factory entrepreneurs and large fruit plantation owners.  
692 These households in small towns benefit from diverse incomes with at least 3 contributory  
693 persons, including family members working outside Indonesia or in large Java cities. They  
694 own 2 or more motorbikes, sometimes 1 car or a small truck, TV and all electronic appliances.  
695 They live in large, well-maintained houses, occasionally including a big shop (about 3,600 to  
696 7,200 US\$). Among the fourth class, rare (2%) households benefit from quite high income (by  
697 Indonesian standard) from business managers and government officials in *Kecamatan*. They  
698 live in large, decorated, high-quality houses with 2+ floors (which cost 80 to 130 times the  
699 average monthly wage), one expensive car or a truck, several motorbikes, and modern  
700 electronic appliances. Families have savings and private insurance, while one or two of their  
701 members sending money from abroad.

702 As a result, the economic situation of rural *dusun* and small towns around Semeru show that  
703 low-income households prevail, whereas high-income households are rare. The low-income  
704 type (i.e., between 122 and 165 US\$/month), barely above the poverty line (average monthly  
705 wage of 122 US\$ as of 2019), represents 44% of the households. At least 22% of households  
706 remain below this poverty threshold (Fig. 4; see 5.3.1). The rate of population living in poor  
707 conditions around the volcano thus is double the average 9.8% nationwide (BPS, 2017).  
708 People living in extreme poverty or exclusion, however, remain lower, as available cheap  
709 food, informal jobs, and solidarity networks and subsidies from religious associations enable  
710 the lowest-income, oldest or disabled people to survive.

#### 711 4. PREPAREDNESS RESULTS

712 We elaborated on respondent preparedness in case of imminent eruption and evacuation based  
713 on the active variables from: (1) hazard knowledge versus risk perception and associated  
714 variables (Surveys B and C+D2), and (2) household resources, assets, and the economic  
715 categorization (Surveys D1 and E). In addition, a few illustrative categories were taken from  
716 Survey A and ESD Table 1 (e.g., exposure based on household location), and the exposure  
717 index score of neighbourhoods (Thouret et al. 2021, in review). Thus, hierarchical  
718 agglomerative clustering (HAC) enabled us to seek correlations between demographics, risk  
719 awareness/preparedness and socio-economic characteristics that help rank population groups



720 (clusters) facing imminent evacuation. A Chi-square test measured the link between the set of  
721 80 variable categories and each cluster (that is the variable of interest), in order to select a  
722 small number (28) of categories that help discriminate clusters with a p-value <0.05 (See  
723 [Table 7](#)). A biplot ([ESD Fig. 2](#)) shows that the majority of variables correlated with  
724 dimensions 1 and 2 are also the most discriminant (e.g., C18, B13, C16, C1, B10, C19, B7,  
725 etc.). These are also the first variables shown in [Table 7](#) using a Chi-square test. [Table 8](#)  
726 displays a frequency analysis computed from all replies to survey questions for each of the  
727 clusters, while [ESD Table 4](#) summarizes high- and low-frequency categories for each cluster.  
728 The HAC factor map ([Fig. 8 5](#)) enables us to distinguish four groups of people among 121  
729 respondents who provided answers to all questions of surveys A, B, C and D ([Table 8](#)). The  
730 four clusters are as follows:

731 Cluster no.1 (green, overlapping with part of Cluster 2, [Fig. 5](#)) gathers c. 41% of people who  
732 have a relatively good hazard knowledge in terms of Semeru's eruptions, lahar occurrence  
733 (see [Table 4](#)), and PDCs, but limited on hazard-zone map meaning and PDCs. They also  
734 benefit from a good risk perception based on experience, memory and education. Self-  
735 confidence, experience and memory, as well as their role in associations may imply a  
736 reasonable behaviour in case of evacuations, the more so as they suffer less handicaps, they  
737 trust warning messages, and they feel that they cannot overcome volcanic events. This cluster  
738 no. 1 includes mostly mature and elder adults, more or less independent, mostly minimally  
739 educated, and relatively exposed to volcanic threats. They usually were born around Semeru  
740 or come from East Java decades ago, and they belong to middle- and low-income households.

741 Cluster no.2 (blue, overlapping with part of Cluster 1) contains 36% of people who show a  
742 regular hazard knowledge: they ignore hazard-zone meaning, but they accurately estimate  
743 lahar occurrence and eruptions. Their regular risk perception stems from evacuation  
744 experience and memory and they trust civil protection works. Most of them are afraid of  
745 lahars (much less of the volcano or PDCs), while a few people present physical, economic or  
746 psychological handicaps. Contrasts between risk perception and feelings play a role on  
747 potentially unruly behaviour in case of evacuation orders, the more so as these people do not  
748 participate in solidarity networks. Cluster no. 2 gathers exposed people with contrasted  
749 resources: mostly adults and elderly people, more or less educated, more or less independent;  
750 and youngsters or young adults, relatively educated but without or low resources. These  
751 people belong to low and middle low-income households, which host workers with two small-  
752 income jobs, small shop keepers, mostly housewives, and school teachers.

753 Cluster no. 3 (purple) regroups a small number of people (15%) who exhibit both poor hazard  
754 knowledge and un-developed risk perception and associated variables. Knowledge on lahar  
755 occurrence, timing, and PDCs is minimal. At the same time, these people show a poor risk  
756 perception due to a very limited experience and short memory about lahar events, as they  
757 arrived in the area in the recent past, and they did not attend school beyond the elementary  
758 level. The combination of poor knowledge and limited perception would not ensure a  
759 reasonable behaviour, as they are poorly involved in solidarity associations and, worse, they  
760 do not trust anyone. Cluster no.3 gathers mature and young adults, mostly minimally  
761 educated, with low resources and/or handicaps, and who usually arrived recently from  
762 Madura or beyond East Java. However, most of them live away from active rivers and  
763 therefore less exposed to impacts. Very low-income households include laborers without land,  
764 employees in small business, street retailers, and elderly or disabled people. This cluster  
765 appears to be the most socially vulnerable.

766 Cluster no. 4 (orange) represents the smallest part (9.0%) of all cohorts, who exhibit a regular  
767 hazard knowledge and a limited risk perception and associated variables. Knowledge and  
768 experience do not play a role on their behaviour in case of evacuation orders, as these people  
769 have a limited trust and need to check warning messages with neighbours. Cluster no. 4  
770 includes adults and older persons, with handicaps therefore dependent on families, and from  
771 local or beyond East Java origin. They live here for more than 25 years. Most of households  
772 are middle income, and a very small number corresponds to the scarce high-income  
773 households hosting several people with multiple jobs. The majority of these less educated  
774 people are highly exposed to volcanic threats and lack awareness or preparedness.

775 In sum, the clusters of people exhibit contrasted relationships between hazard knowledge/risk  
776 perception different, contrasted degrees of awareness and preparedness. Almost 60% of the  
777 respondents do not benefit from sufficient knowledge or perception, which would not ensure  
778 efficient behaviour in case of volcanic crisis. Among them, at least 15% of people need extra  
779 attention from the authorities and risk disaster management staff because they seem un-aware  
780 and un-prepared in case of evacuation. However, about 40% of the respondents claim that  
781 they are prepared to abide by staff orders in case of early warning. This reasonable proportion  
782 may be due to some sort of adjustment to, and compensation with respect to, persistent  
783 volcanic threats.

784 **5. DISCUSSION: HOW DO VILLAGERS BUILD UP RISK TOLERANCE?**

785 We compare household resources with people awareness/preparedness around Semeru to  
786 understand to what extent livelihood can outweigh exposure and compensate the risk to live in  
787 areas affected by chronic lahars and persistent eruptive activity. This section, based on a  
788 statistical analysis, addresses adjustment strategies and opportunities, compared with daily  
789 pitfalls and handicaps (Table 9). Our evaluation narrows in from a national and regional scale  
790 (Indonesia, Java, East Java province) to a local scale (Semeru area, villages) in order to obtain  
791 micro-economic criteria beyond macro-economic data.

### 792 **5.1. Coping adjustment strategies to continued exposure to volcanic threats**

793 Like communities living around active volcanoes such as Pinatubo (Gaillard, 2007, 2008) and  
794 Tungurahua (Tobin and Whitehead, 2002; Few et al., 2017), Semeru's populations have long  
795 adjusted to the hostile environment by exploiting a large gamut of coping strategies that either  
796 modify the effects of hazards, plan potential loss or share actual loss (e.g., Wisner et al., 2004;  
797 Chester, 2005).

798 Top-down (governmental) preventive strategies include civil defense works along the active  
799 rivers, built by the *Semeru Balai* (in Lumajang) using the Japanese 'sabo' methodology:  
800 dykes along, and check dams across the principal, active rivers were constructed in 1970-  
801 1980. Semeru's activity has been monitored by one Observatory since 1953, the hazard-zone  
802 map dates back to 1969 (revised by Siswamidjyo et al., 1997), rusty road signs warn about  
803 lahars, and a few evacuation shelters are planned in sheds or sport fields.

804 Impact-minimizing (governmental) strategies include evacuation signs and roads near the  
805 active rivers, a radio network for workers in river channels, an early warning system based on  
806 antennas in houses near the most exposed *dusuns* close to the volcano, and staff of the  
807 regional BNPB offices. Relief operations are conducted by local rescue teams (e.g., *Laskar*  
808 *Semeru*) along with the Green Cross following eruptions and lahars (e.g., 1994-1995, 2002,  
809 2021), such as *Kampung Siaga Bencana* ('village prepared to risk disaster'), gathering  
810 volunteers who are trained by BNPB staff (Fig 7B, graphs 28-31). Evacuation drills have been  
811 led by BNPB staff every three years or so. Post-event coping strategies include construction  
812 of solid bridges and reconstruction of roads and shelters, but no resettlement program was  
813 ever implemented. No proactive actions such as land planning or building retrofitting was  
814 launched so far.

### 815 **5.2. Benefits and opportunities can compensate for adversity and ensure coping capacity**

816 In addition to the top-down measures taken to manage social vulnerability and the persistent  
817 threat from volcanic activity, local communities have themselves adapted in order to tolerate  
818 and eventually ‘domesticate’ volcanic risk around Semeru. This is a result of benefits attained  
819 by changes in production strategy and new opportunities that broaden income sources (Table  
820 10).

### 821 **5.2.1. Intrinsic environmental advantages around Semeru**

822 Semeru’s population, like others living around active volcanoes in the tropical zone, benefits  
823 from environmental advantages that help them thrive despite the hostile, chronic eruptive and  
824 lahar activity. These advantages stem from the volcanic mountain on which soil, humid and  
825 warm low-latitude climate, and biodiversity foster a wide range of crops across five  
826 ecological belts despite recent, abrupt environmental impacts (Lavigne and Gunnell, 2006):  
827 (1) wet rice terraces in lowland < 600 m asl with fish pools, coconuts, palm and banana trees,  
828 maize and tobacco; (2) the more diversified subequatorial middle belt (600-900 m) combines  
829 horticultural commodities, tropical fruits, and cattle; (3) the subtropical belt (700-900 m up to  
830 1,300 m) includes coffee and cocoa plantations with clover and *salak* (snake fruit); (4) the wet  
831 and cool mountain belt (1,300-2,000 m) is home to the secondary forest with clearings open  
832 by slash-and-burn agriculture mixed with agroforestry, corn and vegetables; (5) the rainforest  
833 draping the cooler mountain slopes between 1,300 m and 2,200 m provides wood and fodder,  
834 while the bare summit cone above 2200 m is forbidden to access. Other intrinsic advantages  
835 include: 1) Profuse water from intense and long-lasting rainfall on the Java’s highest  
836 mountain (3676 m) and water circulation along impervious layers in a composite volcano; 2)  
837 Periodic nutrient enrichment of soil due to recurrent tephra-falls, and; 3) Early adoption of  
838 wet rice cultivation, since the Middle Age kingdoms in Java, having supported high rural  
839 population densities.

### 840 **5.2.2. From traditional to diversified livelihood around Semeru**

841 Livelihood is the command an individual, family or other social group has over an income  
842 and/or bundles of resources that can be used or exchanged to satisfy its needs (Wisner et al.,  
843 2004). Five groups of activities provide opportunities and incomes that increase the ability of  
844 Semeru’s population to compensate for the impacts of hazards to which they are exposed.  
845 1. A diversity of crops enables people to adopt a market-oriented agriculture strategy and  
846 collectors to sell outputs to town markets: not only rice and vegetables, but high-value coffee,  
847 cocoa, tropical fruits and spices exported across Java and to Bali. Villagers have long

848 harvested several crops at the same time and developed crop and craft trade (wood, fabric,  
849 jewels) inside and outside *Desa* and urban centres (e.g., Dampit on the SW flank, Pronojiwo  
850 on the S flank, Pasirian on the SE flank, Senduro, Tempeh and Lumajang on the East slopes).  
851 Gainful crops are (1) rice and *palawija* (corn, sweet potato and manioc, occupying rice fields  
852 during the dry season) alternating with sugar cane or tobacco, (2) a variety of nine vegetables  
853 and three spices (chili, clover, and cinnamon); (3) fruits: bananas and salak, and; (4)  
854 plantations: coffee beans with banana and coconut trees, vanilla, agroforestry (sengon:  
855 *Paraserianthes falcataria* with pineapple), natural rubber and vanilla.

856 2. A pivotal, yet traditional asset in Java rural *dusuns* is animal husbandry, ranked in  
857 economic order (Semeru's *dusun* are no exception): almost every household owns poultry for  
858 eggs and meat; half of the households own a few sheep or goats (cost 140 to 210-280 US\$)  
859 for milk and meat. Buffaloes, stall fed in wood sheds for meat and plowing *sawah* terraces  
860 (cost c.1,080 US\$), are privileges of high-income households.

861 3. About 17% of all houses in surveyed *dusun* host a shop (c. 17% per *dusun*; [ESD Table 1](#))  
862 that ensure minimum income to housewives: with *warung* (basic restaurants) they provide  
863 small household items, food and beverage. Rare big shops resemble mini-markets in *Desa*,  
864 while markets animate the towns of Pronojiwo, Senduro, Pasirian with many shops selling  
865 garments, fabric, house and garden tools, combustibles, and modern life items. Collectors  
866 gather and sell vegetables, spices, eggs and fruits to the urban markets

867 4. "Circular" migration between rural and cities in connection with temporary jobs is a long  
868 habit in Java, and around Semeru as well. Temporary migration, involving almost 19% of  
869 members of surveyed households, mostly young men (masons, drivers) and women  
870 (housemaids), has increased over the past 20 years. Approximately half of them find jobs in  
871 the large cities of Malang, Surabaya, Jakarta, in Bali, and another half outside Indonesia (most  
872 in Malaysia, much less in Singapore, Taiwan, Hong Kong, and the Netherlands). A  
873 fundamental asset is money transfer from emergent and developed countries; although the  
874 amount of money remains unknown, it is far from negligible because a few people declared  
875 that outside money and trade benefits have enabled them to build a regular type-3 house  
876 (about 2,500 to 3,000 US\$) ([ESD Figs. 8A, B](#)).

877 5. Transport links using buses, minivans and motorbike-taxis provide jobs to many drivers  
878 transporting ever-moving populations to cities around Semeru such as Malang to the W,  
879 Dampit-Turen to the SW, Pasirian, Tempeh and Lumajang to the East. A large number of

880 civil servants, police and security staff and health centres also find small-income jobs in  
881 government offices and essential services in *Desa* and *Kecamatan*.

### 882 **5.2.3. Recent opportunities and additional incomes**

883 Over the past 20 years, access to diverse opportunities and new income sources helps  
884 compensate daily hardships and tolerate the impacts of chronic threats. We consider new  
885 income sources as innovations or cultural responses that contribute to increasing resilience  
886 around Semeru as well as in East Java (e.g., [Torrence, 2016](#)).

887 1. Fruits such as coconut, banana, peanut, durian, and the recent development of high-value  
888 salak (0.15-0.22 US\$/kg/tree, 1000-2000 trees/ha), as well as *kesemek* (Asian persimmon) on  
889 small plots < 500 m<sup>2</sup> (0.15-0.40 US\$ /kg, 500 quintal/year), and several spices together with  
890 coffee beans (1.60 US\$/kg), are transported towards the Lumajang, Malang or Surabaya trade  
891 centres, across and beyond Java. Poorly developed soils on lahar deposits support plantation  
892 areas, either the traditional teak, or the most recent agroforestry (*sengon*) for plywood and  
893 light timber. The fast-growing *sengon*, resistant to diseases, provides more routine income to  
894 villagers ([Siregar et al., 2007](#)) ([ESD Figure 1](#)).

895 2. Other non-farming activities include housing construction, timber and furniture industry  
896 using teak and *sengon* wood (e.g., in suburbs of Senduro), repair garage so profitable thanks  
897 to scores of motorbikes, which represent a relatively moderate expense (105 US\$), and a  
898 practical asset for all households except for the low-income ones.

899 3. The extraction of material from river lahar and PDC deposits is a traditional activity, which  
900 recorded a spectacular growth over the past 25 years around active volcanoes (e.g., Merapi, [de](#)  
901 [Bélizal, 2013](#)) and more recently around Semeru from the active rivers such as the K. Bank-  
902 Kembar near Pronojiwo and along the major drainages to the East and South ([Fig. 3](#)). This  
903 private and informal sector hires hundreds of people working in alluvial plains and hundreds  
904 of trucks transporting sand and gravel to factories in Lumajang or Malang and as far as  
905 Surabaya. Material extraction forms a socio-economic system that attracts migrants from both  
906 regencies and beyond; 35 to 50% young men in each of our surveyed *dusuns* use this  
907 temporary resource to add to their income from traditional farm work, with it paying three  
908 times more than a laborer's daily wage. The mining sector disrupts the traditional rural system  
909 well beyond villages located near the lahar-conveying rivers ([de Bélizal et al., 2012](#)). The  
910 mining sector supports an obscure system: lack of legal organization, multiple actors,

911 privatization of land in river channels, workforce hired outside the local market and beyond  
912 the regency, acute increase in truck business, and heavy traffic along narrow, deteriorated  
913 roads, where workers are highly vulnerable to lahar impacts.

914 4. Although Semeru is distant from the main international tourist circuits and poorly  
915 connected to the rest of Java, touristic flux increased over the past 15 years. In addition to the  
916 pilgrimage to the Hindu temples in Senduro (e.g., largest ‘Mandara Giri Semeru Agung’  
917 temple across East Java), regional tourism has expanded towards this town from the cities of  
918 Lumajang and Jember, and natural attractions such as waterfalls along K. Glidik, while  
919 increasing treks to the volcano summit and lakes have attracted both national and international  
920 tourists. This influx has launched the opening of homestays along the national road no. 3  
921 (Malang-Dampit-Lumajang) and several guest houses in Senduro. Tourism, an offspring to  
922 international circuits visiting the Tengger-Bromo caldera, will provide more jobs in the near  
923 future, but road and railway networks need improvement.

### 924 **5.3. Detrimental conditions may hinder tolerance to volcanic threats**

925 [Table 9](#) summarises the basis for, and hindrances to, the population’s tolerance and adaptive  
926 capacity to volcanic threats from Semeru.

#### 927 **5.3.1. Top-down risk communication, false security, and informal workforce**

928 Education, partnership and dialogue, which form the foundation of risk communication, are  
929 much less disseminated than emergency warnings and information provision. This reflects  
930 that the participatory approach is not well developed and the emergency procedure seems  
931 hierarchical ([Mei and Lavigne, 2012](#); [de Bélizal et al., 2012](#); [Bakkour et al, 2015](#)). A false  
932 sense of security may be instilled in the population by gurus, and in *dusuns* near rivers behind  
933 costly, but not well-maintained, dykes and check dams ([ESD Fig. 1](#)). The civil defense works  
934 become a double-edged sword, promoting debates between engineers and authorities (e.g.,  
935 [Lube et al., 2011](#))

936 Informal activities still play a pivotal role in rural *dusuns*. The informal sector, not subject to  
937 national labour legislation, income taxes, social protection or entitlement to employment  
938 benefits, amounts to c. 60% of the workforce in Indonesia ([Rothenberg et al., 2016](#)). We  
939 estimate that about 70% of young and adult men (perhaps less amongst housewives) in the  
940 surveyed *dusuns* and small towns around Semeru dedicate their time to informal activities  
941 ([ESD Fig. 8A, graph 8](#)). These encompass, in decreasing number: a majority of un-skilled

942 laborers in agriculture and a growing sector of workers in material extraction, garages, sheds  
943 and little shops; micro retailers in town markets; housemaids in well-off households and small  
944 street restaurants; truck and motorbike taxi drivers; and street vendors. Informal workers have  
945 a limited access to safety nets so they remain vulnerable to health hazards. Poorly included in  
946 solidarity networks, informal workers often become the victims of economic downturns and  
947 natural disasters.

### 948 **5.3.2. Poor insurance protection, lack of high-school education and inequalities**

949 Rural populations are not well protected in terms of insurance, as only very-low income, elder  
950 persons benefit from basic government provision, while a minority of high-income people can  
951 obtain private insurance from the social security agency *Badan Penyelenggara Jaminan*  
952 *Sosial Kesehatan* (BPJS). The proportion (48%) of the Indonesian population protected by  
953 some kind of health insurance is lower in rural *dusuns*. In 2014, Indonesia launched the  
954 compulsory health insurance scheme called *Jaminan Kesehatan Nasional* (JKN), which  
955 makes basic medical treatment and facilities available to all citizens, but it fails to improve  
956 healthcare infrastructure in remote areas. Health centres (*Puskesmas*) have improved in  
957 districts and small dispensaries in *Desa*, but there are only four Hospitals (i.e., less than one  
958 bed for 2,500 inhabitants) around Semeru in Pronojiwo, Candipuro, Pasirian and Dampit  
959 (ESD Fig. 1).

960 Loans and micro-loans do exist, but a majority of people cannot get access to them. As much  
961 as 64% of very low- and low-income households are poorly protected when a natural disaster  
962 occurs around Semeru, particularly for the far-flung lahars along alluvial plains. Factors that  
963 enable people to survive disaster impacts and curb the number of fatalities is the network of  
964 associations and solidarity, the mitigation policy led by BNPB over the past 20 years, the  
965 shared trust in local officials, and the compelling evacuation orders (e.g., Mei et al., 2013).

966 School is mandatory between age 6 and 18 years. The overall illiteracy rate has officially  
967 decreased in Indonesia (2.0% in 2019 from 7.0% in 2015), but our surveys estimate this rate  
968 to be at least 10% around Semeru, particularly among mature adults and elderly people (Fig.  
969 4). About 10% (mostly elder and disabled people) receive no education at all; if we add 43%  
970 of the people who attended only elementary school, as much as 53% of the population  
971 prevailing in rural areas can be termed un-skilled, a proportion that diminishes in urban  
972 centres (ESD Fig. 5, graph 5). The low education in rural and remote *dusuns* and the limited  
973 access to high-income jobs translates to less sensible behaviour in case of evacuation.



974 Inequality has its roots in uneven access to high education and skilled jobs, and economic  
975 disparities between rural villages and cities. Inequality within villages is due to many daily  
976 hardships such as high inflation rate (7% per year), cost of basic food, demographic growth  
977 rate, and ethnical prejudice. The situation has improved in recent years (up to 2020 at the  
978 onset of COVID-19) thanks to the government reforms and village solidarity networks, but  
979 most of rural *dusuns* on Semeru's slopes remain isolated from modern infrastructure  
980 development except along the national road no.3 between Lumajang and Dampit.

#### 981 **5.4. Solidarity networks and beliefs may improve adaptive capacity**

982 Among other factors, culture beliefs and solidarity networks, which play a critical role in rural  
983 life, ensure population resilience facing life hardships and natural disasters (Lane et al., 2003;  
984 Lavigne et al., 2008; Dove, 2007, 2008; Barclay et al., 2015; Few et al., 2017; Torrence,  
985 2016, 2019; Favereau et al., 2018; Andreastuti et al., 2019). A majority of people living on  
986 Semeru tolerate both the destructive and creative effects of eruptive activity (Tables 9, 10).

987 1. Sense of community is rooted in traditional culture in Java. Many types of associations  
988 maintain social links, labor power and exchanges in daily life around Semeru alike across  
989 Java. *Gotong royong*, for example, is a widespread mutual assistance in daily activities and all  
990 *dusun* tasks. In the multi-ethnic and social groups that form Indonesia, several associations  
991 gather people around religion, rural activities, and sports. Women meet in *Pemberdayaan*  
992 *Kesejahteraan Keluarga* associations for daily work, assistance, and entertainment. Social  
993 organizations or associations care for young people through farm outputs, sport and religion.  
994 Local *dusun* leaders, local rescue and relief teams, BNPB staff all play a role in cementing  
995 social capital between socio-economic groups at the local scale. Indonesian Green Cross and  
996 charity associations offer subsidies to disabled persons, outreach programs in schools, and  
997 provide food and basic relief in the wake of natural disasters. Chester et al. (2013) pointed out  
998 that although Muslims may assign earthquake and eruption losses to divine punishment, the  
999 religion does not, however, inhibit the introduction of programs of loss reduction (rescue,  
1000 relief and post-event institutional charity). Social scientists bemoan that solidarity networks  
1001 loose strength among young generations and young migrant adults over the early 21st Century  
1002 (Effendi, 2013).

1003 2. Rituals remain a tradition in rural *dusuns* in Java: at least 40% of respondents declare some  
1004 sort of rituals to worship or respect Nature, in particular volcano and water around Semeru  
1005 (Fig. 6B g34). Although almost 61% declare that they do not follow any rituals, many

1006 respondents may not want to disclose this sensitive belief (c. 12% do not provide an answer).  
1007 Cultural beliefs and rituals devoted to Nature in general, water and volcano in particular, are  
1008 widespread in Java (Dove, 2007, 2008) and traditional beliefs remain, underlying the common  
1009 Muslim religion. The Javanese culture keeps old, pre-Muslim, spiritual traditions alive,  
1010 stemming from animism, Hinduism or Buddhism, which flourished before the 16th century in  
1011 Javanese kingdoms. Under the Sunni Muslim religion, which 95% of the population follow,  
1012 villagers perpetuate, however, an unearthly and sacred link with the territory in which they  
1013 live. The complex interactions between volcano, nature and territory with Humans are  
1014 illustrated in Hindu religion, and at the largest ‘*Mandara Giri Semeru Agung*’ Hindu temple  
1015 devoted to Semeru and Agung (Bali) in Senduro (Harsana and Karda, 2016). Hindu rituals  
1016 and Balinese spirituality are practiced in several small Hindu temples inspired by the  
1017 Majapahit kingdom (13-16th century) style in East Java, in particular in Senduro.

1018 Traditional beliefs help people maintain some equilibrium between the irritable mountain of  
1019 fire (*Gunung Api*) and nurturing water or land (e.g., Dove, 2008). Rituals are well kept as  
1020 processions to river springs (e.g., K. Koboan) and/or small temples on volcano slopes and  
1021 personal prayers honor the powerful *Gunung Api*. A few elderly persons are considered as  
1022 sacred such as the *juru kunci* (volcano key keeper and imam) or cemetery keepers who  
1023 communicate with ancestral spirits ensure some equilibrium between volcanoes and  
1024 communities (Dove, 2007, 2008; Lavigne et al., 2008). The *juru kunci* is considered as a  
1025 supranatural being, who exemplifies the complex cultural interactions between volcanoes and  
1026 Humans both at Merapi and Semeru. Rituals and sacred elder people (for example the  
1027 cemetery keeper in Rowobaung), which operate as a syncretism between ancestral beliefs and  
1028 Muslim practice, should be accounted for when scientists and risk management staff seek to  
1029 persuade local people to watch volcano activity and evacuate. The example of the charismatic  
1030 Mbah Maridjan, who lived on the south flank of Merapi (Lavigne et al., 2017), is well known  
1031 among dwellers around Semeru, and his death and that of his followers during the 2010  
1032 eruption, together with videos of PDCs, were warning and fearful signs for people that we  
1033 interviewed.

1034 Rituals and beliefs as well as spirituality are cultural assets and social tools, which allow  
1035 villagers around active Semeru to apprehend and ‘domesticate’ irritable ‘Mother Nature’. This  
1036 tolerance is akin to adaptive capacity, as rural population shows a ‘risk culture’ rooted in daily  
1037 life, enabling a majority to abide by evacuation orders. The risk culture and attachment to

1038 place makes the volcano an asset providing additional incomes through ash to soil, rain to rice  
1039 and tourism to wallets. The downside effect of volcano attractiveness is that recent  
1040 opportunities bring new people to the area, with 22 % of our respondents having arrived  
1041 around Semeru over the past 25 years. Recent migrants without risk culture may create a  
1042 disequilibrium between resources and benefits; for example, exposure has increased in  
1043 particular along active valleys (K. Bang, Kembar and Sat near Pronojiwo) where informal  
1044 workers are un-prepared and do not belong to local networks. These are vulnerable, temporary  
1045 migrants with unequal or unreciprocated dependence on their village neighbours.

## 1046 **5.5. From risk tolerance to adaptive capacity and resilience**

1047 [Table 10](#) displays parameters to estimate resilience among Semeru's population. Results  
1048 acquired on exposure, hazard knowledge–risk perception and associated variables–  
1049 preparedness around the volcano are significant when compared with studies of community  
1050 response to volcanic crises in Indonesia, e.g., at Bromo ([Bachri et al., 2015](#)) and Merapi, Java  
1051 ([Dove, 2008](#); [Lavigne et al. 2008](#); [Mei et al., 2012](#); [Napsiah et al., 2017](#)), and Sinabung,  
1052 Sumatra ([Andreastuti et al., 2019](#)). The latter study compares the ongoing Sinabung and 2014  
1053 Kelud unrest cases to highlight factors that influence a community response at the time of an  
1054 imminent eruption. A number of factors unravel the situation around Semeru, which is  
1055 halfway between the Sinabung and Kelud cases in terms of risk management and obstacles to  
1056 community adaptive capacity ([Tables 9, 10](#)): 1) Hazard knowledge is fair in *dusuns* located  
1057 near rivers or affected in the recent past, but regular elsewhere. 2) Experience remains more  
1058 restricted on PDCs than about lahars and tephra-fall. 3) Dissemination of risk communication,  
1059 which traditionally operates top down, is poor during periods of mild activity. 4) Scientists  
1060 and information provision are trusted, but direct exchange between scientists, officials and  
1061 villagers are poorly developed. 5) A majority of villagers are motivated to be involved in  
1062 disaster mitigation, but their motivation is not used by relief teams. 6) Stakeholders seem less  
1063 involved than local relief teams in risk management policy. 7) Evacuation is promoted  
1064 officially in case of large eruptions, but auto-evacuation happens, and many villagers check  
1065 early-warning messages, leading to inaction. 8) The effectiveness of local and regional  
1066 response actions is recognized, but questioned at national level. 9) Local/regional and national  
1067 risk management staff may be competing in case of crisis response. 10) Early warning,  
1068 storage facility and shelters may avail during large eruptions, but people experience a sense of  
1069 false security during long periods of mild activity. 11) Coordination and planning apply  
1070 during large crises, but they should be disseminated during long-lasting volcano unrest. As a

1071 result, the anticipation of disaster is slower than its propagation during large eruptions, thus  
1072 delaying efficient disaster management. The conservative risk management policy likely  
1073 suffices during periods of mild activity, but it might lead to future disasters in case of large  
1074 eruptions or destructive lahars. This has been the case during the large January 2022  
1075 catastrophic eruption (CVGHM, unpubl. data).

## 1076 **5.6. Implications for the improvement of resilience and disaster risk mitigation**

1077 Recently, [Freitas Guimarães et al. \(2021\)](#) recommended a set of measures to reduce  
1078 vulnerability and increase resilience from a study of 123 Latin American volcanoes: e.g., by  
1079 creating accessibility to infrastructure, carrying out risk assessment studies, implementing  
1080 early warning systems, developing emergency plans, and promoting educational activities. At  
1081 the scale of Semeru's most hazardous zones, early warning systems (radio antenna) for  
1082 evacuations, emergency signs near active rivers, and educational activities such as evacuation  
1083 exercises have been promoted. More critical for risk management, future mitigation policy  
1084 and dialogue from the officials should reach out to two groups of people (Dr and Cr)  
1085 identified from the survey on risk perception and associated variables leading to awareness  
1086 and preparedness ([Table 5](#)). The group Dr (19-21.5% of the cohort in surveys C+D2) seems  
1087 unaware, distrustful, and may be poorly prepared to abide by evacuation orders and measures  
1088 to reduce their handicaps. This group includes the low or very low-income, old or disabled  
1089 persons, with minimal education and poor knowledge on volcanic hazards. The larger group  
1090 Cr (26-26.5% of the cohort), who feels insecure and wavering in case of crisis, should also be  
1091 helped out by the local officials and village leaders or associations through educational  
1092 activities and simulation exercises. The aim is to share evacuation experiences and improve  
1093 empowerment or self-confidence.

1094 There are broader implications of our study. First, the findings that social conditions may  
1095 matter more than the level of income in reducing the number of deaths and economic loss,  
1096 likewise indicates that a societal, not financial, nature of intervention is needed to  
1097 significantly address vulnerability among at-risk villages around active volcanoes.  
1098 Sustainability calls for the provision of basic services for all, and the protection of vulnerable  
1099 groups. Second, Disaster Risk Reduction (DRR) measures around Semeru as well as other  
1100 active volcanoes must include an appropriate mix of structural and non-structural measures  
1101 that aim to improve resilience. As [Rose \(2004\)](#) concluded, the measurement of resilience is  
1102 important because it enables us to evaluate an important strategy for reducing economic losses

1103 from disasters. Failure to incorporate resilience in loss estimation will result in inflated  
1104 assessments of business interruption from disasters. Failure to include resilience in policy-  
1105 making will result in missed opportunities to reduce losses.

## 1106 **6. Concluding remarks**

1107 1. The local-scale approach and face-to-face interviews immersed in neighbourhoods together  
1108 with statistical techniques helped define five socio-economic categories in 15 rural *dusun*  
1109 and small towns. Surveys highlight widespread economic constraints: two thirds of  
1110 households are low- to very-low income. As many as 40% of villagers around Semeru are  
1111 socially vulnerable, as they meet daily hardships and restricted access to resources.

1112 2. Economic hardships and lack of empowerment would prevent at least 40% of exposed  
1113 people from behaving cautiously once they have been told to evacuate. People exhibit  
1114 contrasted hazard knowledge/risk perception/awareness relationships. Almost 60% of the  
1115 respondents do not benefit from sufficient hazard knowledge and/or risk perception and  
1116 associated variables, which may not ensure efficient behaviour in case of imminent eruption.  
1117 Of our respondents, at least 19% are unskilled and with a lack of trust in authorities, thus  
1118 poorly prepared to be evacuated from very low-income households. This group in particular  
1119 requires more attention from the authorities and risk disaster management staff.

1120 3. The contrasted knowledge/perception levels mean that a majority of villagers may be on  
1121 alert for daily volcano unrest, but many downplay the effects of large volcanic crises.  
1122 However, about 40% of the respondents declare to be prepared to abide by official early  
1123 warning orders. Sense of community and culture beliefs in *dusun* as well as new resource  
1124 opportunities enable them to improve their adaptive capacity to risk.

1125 4. Results can help authorities and the risk management staff to improve hazard knowledge at  
1126 school, risk communication integrating beliefs, and a bottom-up, participatory approach  
1127 involving more collaboration between villagers, leaders, local associations, and BNPB. Close  
1128 coordination between government and community is required. Future mitigation policy and  
1129 dialogue from the officials should reach out to at least 19% of villagers who seem poorly  
1130 prepared to abide by evacuation orders in order to help reduce their handicaps.

1131 5. As a consequence of an extensive record of exposure to chronic threats, populations around  
1132 Semeru have nevertheless promoted resilience. Such adaptive capacity provides a frame of

1133 reference for disaster-prone countries. However, to maintain a steady-state awareness and  
1134 preparedness among dwellers living on continuously active volcanoes is more challenging  
1135 than around their counterparts whose brief eruptions are interspersed within long-lasting  
1136 periods of quiescence.

## 1137 **Acknowledgments**

1138 The ANR 'RiskAdapt' research project funded fieldwork and laboratory analyses. This  
1139 research was also financed by the French government IDEX-ISITE initiative 16-IDEX-0001  
1140 (CAP 20-25). We are grateful to DIKTI (Directorate General of Higher Education, Ministry  
1141 of National Education of Indonesia), who bestowed two research permits to the first author.  
1142 We acknowledge the scientific support from Dr. A.-F. Yao-Lafourcade (Laboratory of  
1143 Mathematics, UCA), MSc Isna Pujiastuti (Faculty of Geography, University Gadjah Mada,  
1144 Yogyakarta), and MSc. Muhammad Syaif Habi, F. Muhammad A.W. Hasan (Faculty of  
1145 Agriculture, IPB University, Bogor). We thank Mr. Mahjum and Pak Sam for their logistical  
1146 support. SFJ would like to acknowledge funding from the National Research Foundation  
1147 Singapore and the Singapore Ministry of Education under the research centres of excellence  
1148 initiative. This work comprises Earth Observatory of Singapore (EOS) contribution no. 418.

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#### 1344 **Table captions**

1345 **Table 1.** Setting of surveys carried out in *dusuns* (sub-villages): administrative units, location,  
1346 surface area, people density, and number of surveys in each *dusun*. Symbol meaning: \* Data  
1347 from BPS reports, Kecamatan Dalam Angka 2019, and 2018 for Tamansatryan,  
1348 Sumberwuluh, Candipuro. \*\*A *dusun* usually includes 4 to 5 RukunWarga (RW, a  
1349 neighborhood with 50 to 75 houses). A RW includes usually 3 to 9 RukunTetanga (RT, a  
1350 block with 20 to 25 houses). We conducted surveys at the scale of RWs, including more than  
1351 one questionnaire per RT. A block (neighbourhood) is equivalent to RT.

1352 **Table 2.** Observations, methods, techniques and purposes of the statistical analysis conducted  
1353 on the datasets from five surveys. Observations are respondents in Surveys A, B, C and  
1354 households in Surveys D1-2 and E cases.

1355 **Table 3.** Five socio-demographic groups among 279 respondents based on the frequency  
1356 analysis of the Survey A dataset. The frequency analysis used the distribution of cross tables  
1357 of relevant categories such as age, education level, socio-professional category, resources and

1358 geographical origin. We also normalized the values obtained under each group of questions 1  
1359 to 2.

1360 **Table 4.** Hazard knowledge levels of respondents based on the frequency analysis of the  
1361 Survey B dataset. The frequency analysis involved three operations: 1) sum of coded  
1362 thresholds for each of the variable categories, 2) the mean of the sum to establish a threshold  
1363 between two levels, and 3) another mean value of these two levels in order to obtain four  
1364 levels. We also normalized the values obtained under each group of questions 1 to 5.

1365 **Table 5.** Categories of risk perception and its associated variables, awareness and  
1366 preparedness of respondents based on the frequency analysis on the Survey C and D2 dataset.  
1367 Similar methods as used in Table 4.

1368 **Table 6.** Socio-economic households, resources and belongings based on the frequency  
1369 analysis of the Survey D1 dataset. Similar methods as used in Table 4 and 5.

1370 **Table 7.** Chi-square test on variables that determine HAC clusters (see Fig. 5). The Chi-  
1371 square test aims to quantify the sum of deviations between the observed counts and theoretical  
1372 counts from a table of contingency using a single statistical quantity. Then the test compares  
1373 the value of this single statistical quantity with the probability that the latter appears in the  
1374 case of a series of random draws, while taking account of the size of the table (number of  
1375 freedom degree).

1376 **Table 8.** Hierarchical Agglomerative Clustering (HAC) of categories of respondents derived  
1377 from active variables of hazard knowledge and risk perception and its associated variables,  
1378 socio-economic classes correlated with illustrative variables from surveys A and E (see Figure  
1379 5 and ESDS Table 4).

1380 **Table 9.** Constraints and factors that hinder or help Semeru villagers to adjust to potential  
1381 loss, compensate daily hardships or handicaps, and thrive while tolerating persistent volcanic  
1382 threats. \*see Chester (2005).

1383 **Table 10.** Parameters and obstacles to estimate resilience, the ability to maintain continuity by  
1384 avoiding or withstanding failure, akin to adaptation. These parameters rely on the survey  
1385 results and a review of thoughtful studies (e.g., Gaillard, 2007; Lane et al., 2003; Kelman and  
1386 Mather, 2008; Paton et al., 2008; Haynes et al., 2008a, b; Barclay et al., 2015; Few et al.,  
1387 2017; Favereau et al., 2018; Torrence, 2019; Jones, 2019).

1388 **Figure captions**

1389 **Figure 1.** Research steps and statistical analyses to define and compute socio-economic  
1390 characteristics, and assess hazard knowledge and risk perception [and associated variables](#) to  
1391 evaluate people awareness and preparedness in case of volcanic crises. LH stands for lahars,  
1392 PDC for pyroclastic density currents.

1393 **Figure 2 A.** Map of Semeru volcano and ring plain sitting in the middle of the regencies of  
1394 Laumjang to the east and Malang to the west. Distance circles 9, 12, 18 and 35 km with  
1395 respect to the persistently active vent are dashed lines. Principal cities and towns are  
1396 indicated. Red circle in map **B** points to the Semeru-Tengger massif, East Java. M= Malang,  
1397 S= Surabaya.

1398 **Figure 3.** Hazard-zone map of the Semeru's slopes and ring plain depicting the extent of  
1399 volcanic phenomena in the case of a medium-sized (VEI 3) eruption, based on the 1994, 1995  
1400 and 2002 eruptions and post-eruption lahars (Thouret et al., 2007). The map also shows the  
1401 extent of lahars and floods in the case of a catastrophic eruption (VEI > 3) along valleys  
1402 through the distal south and east ring plain, based on the 1909 and 1981 events and the  
1403 disaster-prone areas map (Bronto et al., VSI, 1996). Initials indicate the surveyed 13 *dusuns*:  
1404 B-K Blubuk, Karangsono, SU Supit, RB Rowobaung, SB Sumbersari, GM Gumuk Mas, CK  
1405 Curah Koboan, KK KajarKuning, TU Tulungrejo, JA Jabon, SM Sumbermulyo, JL  
1406 Jaranglangak, RE Rekesan, and two towns of Pronojiwo and Senduro.

1407 **Figure 4.** Comparison of population socio-demographics and socioeconomic characteristics  
1408 between Semeru (our surveyed *dusuns* in the regency of Lumajang), Java, and Indonesia (Java  
1409 and Indonesia data from [BPS, 2017](#)).

1410 **Figure 5.** Factor map showing four classes of respondents based on hierarchical  
1411 agglomerative clustering and derived from active variables of hazard knowledge and risk  
1412 perception and associated variables correlated with illustrative variables from surveys A, D,  
1413 and E. We did not apply the Benzécri correction to the initial dimensions.

1414 **Electronic Supplement Data ESD**

1415 ESD Text 1. List of questions of the surveys A, B, C, D1, and D2.

1416 ESD Text 2. Main results from Surveys A, B, C+D2, D1, and E.

1417 ESD Table 1. Coordinates of buildings, economic status of respondents, and geographical  
1418 exposure with respect to active valleys.

1419 ESD Table 2. Survey file used for describing the building performance.

1420 ESD Table 3. Structural and architectural typology of buildings (mostly habitat) around  
1421 Semeru. In rural areas, the dwelling floors consist of pounded earth, concrete, or raised wood.  
1422 Wood framing supports walls of woven bamboo matting. Dried palm thatch, tiles, or wood  
1423 cover roofs. In urban areas, floors are made of cement or tile, the framing of the dwellings is  
1424 teak wood, the walls include brick and plaster, and the roofs are made of tile or shingle.

1425 ESD Table 4. List of high- and low-frequency categories determining the four clusters.

1426 ESD Figure 1. Maps showing the setting of the 15 *dusuns* together with the blocks in which  
1427 surveys and statistical analyses. A. Karanguko and Blubuk (Desa Tamansatryan), west flank.  
1428 B. Town of Pronojiwo, Supit-Supit Timur and Rowobaung (Desa Pronojiwo), South flank. C.  
1429 Oro-Oro Ombo (Desa and dusun), Sumberhari, Gumuk Mas, Curah Lengkong (Desa Supit  
1430 Urang), SSE and SE flank. D. Kajar Kuning (Desa Sumberwuluh) and Desa Candipuro, SSE  
1431 flank. E. Tulungrejo and Jabon (Desa Pasrujambe), ESE flank. F. Sumbermulyo,  
1432 Juranglangak, and Rekesan (Desa Senduro), East flank.

1433 ESD Figure 2. Scree plot of eigenvalues, showing the variance (information) retained in each  
1434 dimension, once we applied the Benzécri correction. Amongst 80 dimensions, we selected the  
1435 first eleven as they retain almost 80% of the required information. Then we performed the  
1436 HCA classification using these 11 dimensions.

1437 ESD Figure 3. MCA Biplot showing the correlation between variables and main dimensions 1  
1438 and 2. A shows all variables, while B has enlarged the central part of the plot, highlighting the  
1439 variables that are too close in A.

1440 ESD Figure 4. Fifteen most contributory categories along: A. Dimension 1, and B. Dimension  
1441 2 of MCA. The +sign indicates the positive coordinate of the variable along the dimension,  
1442 whereas the -sign points to the negative coordinate of the variable along the dimension.

1443 ESD Figure 5. Socio-demographic characteristics (graphs 1-7) and geographical origin of the  
1444 respondents (graphs 8-17) from the Survey A dataset. Graphs 1-4 show the number of people  
1445 in each household (graph 1) as a function of age group (graphs 2-4).



1446 ESD Figure 6. Hazard knowledge acquisition among the respondents from the Survey B  
1447 dataset. Graphs 1-11.

1448 ESD Figure 7A. Level of risk perception and associated variables among the respondents  
1449 from the Survey C dataset. Graphs 1-19.

1450 ESD Figure 7B. Level of risk perception and associated variables among the respondents  
1451 from the Survey C dataset. Graphs 20-34.

1452 ESD Figure 8A. Socio-economic categories from the Survey D dataset: Graphs 1-10.

1453 ESD Figure 8B. Socio-economic categories from the Survey D dataset: Graphs 11-17.

1454 Structural typology of buildings from the Survey E dataset, graph 18, and physical  
1455 vulnerability classes of buildings, graph 19 (see [ESD Tables 2 and 3](#)).

1456

# POPULATION SOCIO-DEMOGRAPHIC, ECONOMIC CHARACTERISTICS AND ADAPTIVE CAPACITY

## STATISTICAL APPROACH APPLIED TO SURVEY DATASETS

Univariate & Bivariate analyses, Multiple Correspondence Analysis, and Hierarchical Agglomerative Clustering

### I. Population characteristics (Survey A)

1. Location: village, *dusun*\*, neighbourhood
2. Gender, civil status, age group
3. Household composition (families, people)
4. Socio-professional category
5. Education degree
6. Resource person, monthly income threshold
7. Geographical origin (respondent, relatives)
8. Arrival time and migration

### II. Livelihood and resources (Surveys D1 & E)

1. House, land ownership
2. Livelihood type, resource people
3. Belongings, crops, storage facility
4. Economy exchange inside, outside *dusun*\*
5. Access to evacuation, civil protection work
6. Handicap
7. Financial status, debt and loan
8. Building stock: use, structural types, physical vulnerability categories

### I and II: Defining social vulnerability and socio-economic categories

### Hazard knowledge (Survey B)

1. Volcano name, last eruption date
2. Hazard-zone map: location, zone meaning
3. Hazard type: lahar, PDC, tephra fall
4. Lahar occurrence, arrival time, affected people
5. Eruption and lahar duration
6. Lahar occurrence following eruption
7. Origin of knowledge about LH, PDC, tephra-fall

### Risk perception & associated variables (Surveys C & D2)

1. Main concern (family, daily life, volcano)
2. Sense of community, social capital
3. Direct, indirect, vicarious experience
4. Memory and behaviour
5. Lahar attractiveness
6. Self confidence, empowerment
7. Trust in early warning messages
8. Appreciation on prevention policy
9. Feelings about volcano, LH and PDC

### III. Assessing awareness, preparedness, and behaviour in case of imminent eruption and evacuation

### Evaluation of the adaptive capacity and resilience of Semeru's population

a balance between:

environmental advantages, traditional and diversified livelihood, alternative new resources, additional sources of income, and solidarity networks with detrimental conditions and hindrances

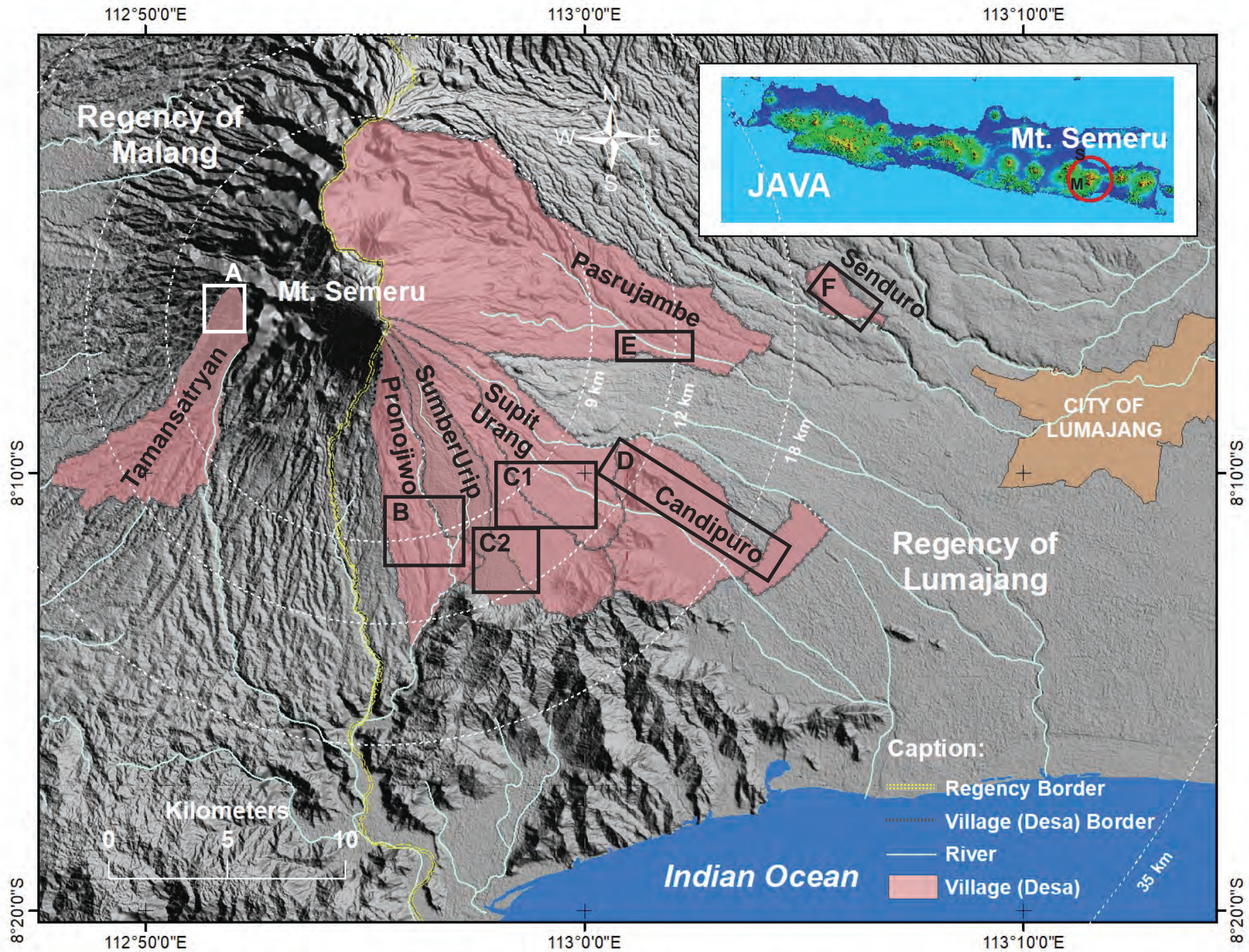
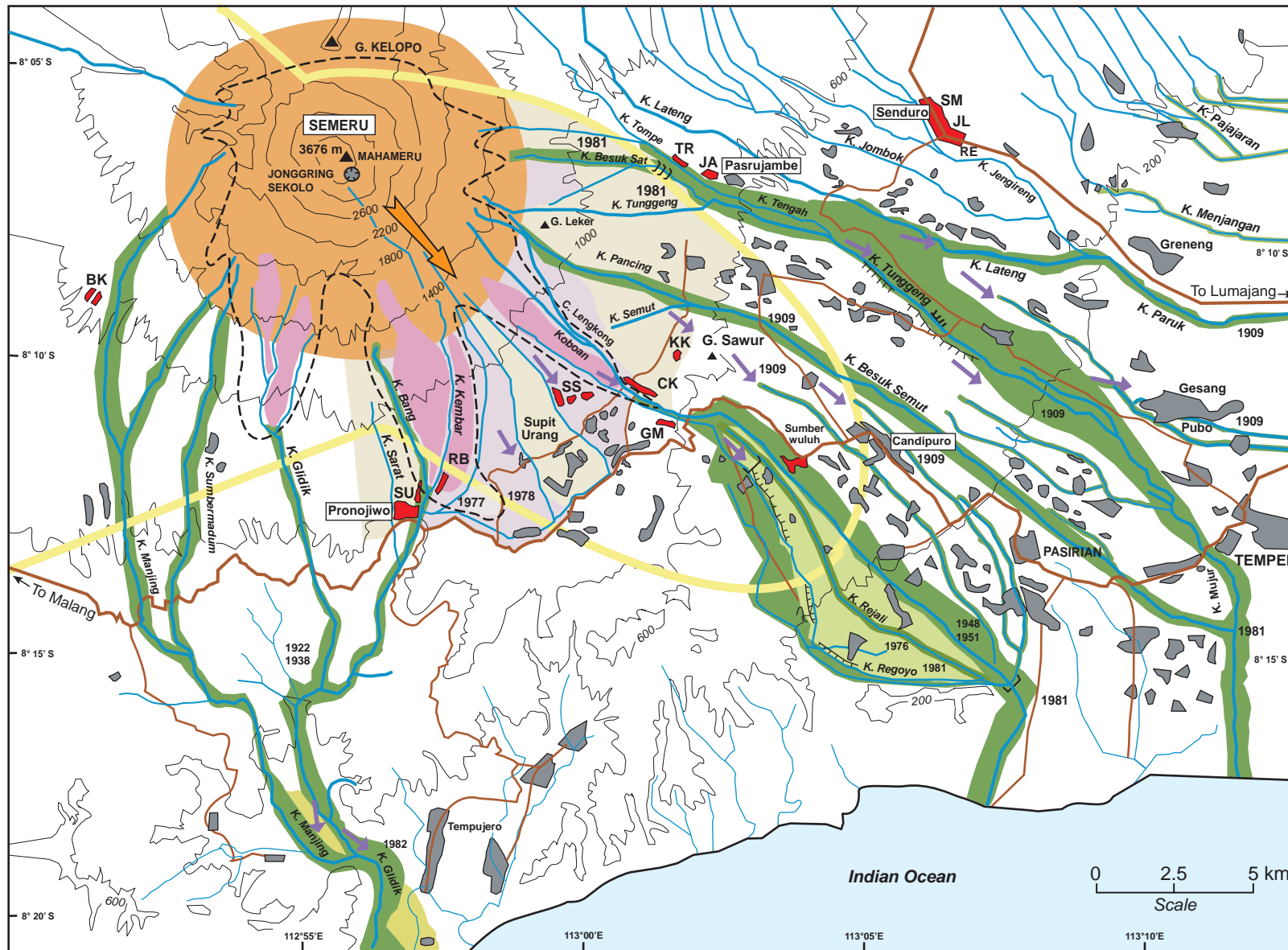


Fig. 2















- |   |  |   |  |
|---|--|---|--|
|  | Areas frequently affected by tephra fallout on annual basis (VEI 2) and ballistics within 5 km                                   |  | Areas likely to be mantled by annual ashfall associated to PDCs and dispersed in case of large eruption: towards East & SE (rain season), West & SW (dry season) |
|  | Boundary of potential pyroclastic density currents (PDCs) in case of VEI > 3 eruption  |  | Valleys swept by large-volume lahars (>1 million m <sup>3</sup> ), e.g., 1909, 1976 and 1981   |
|  | Areas affected by PDCs and companion fallout every 8 to 11 years on average (VEI 3)  |  | Alluvial plains affected by lahars in case of large-scale eruptions (VEI > 3) and/or heavy rainstorm   |
|  | Areas affected by PDCs and companion ashfall due to large VEI > 3 events every 11 to 25 years on average                         |  | Possible overbank and avulsion in case of large-volume lahars  |
|  | Areas likely to be affected by tephra-fall associated with PDCs or by fallout in case of large eruptions                         |  | Dykes and check dams (Sabo) along active valley channels   |
|  | Preferential path (scar of Jenggiring-Seloko) guiding dome-fed rock avalanches, lava flows and pyroclastic flows on annual basis |  | Dusun (sub-village) and small towns under study  |

Fig. 3

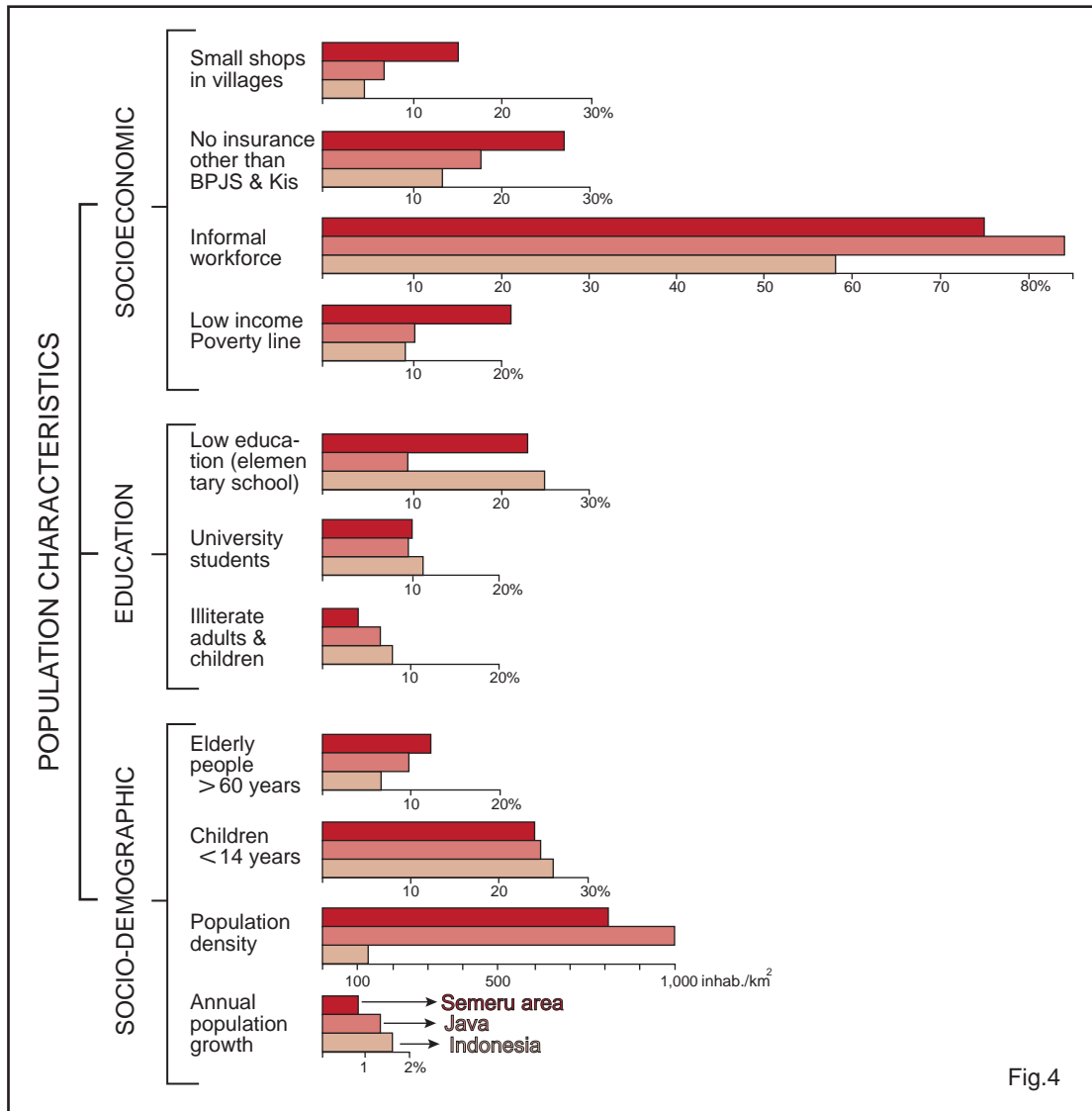


Fig.4

Factor map

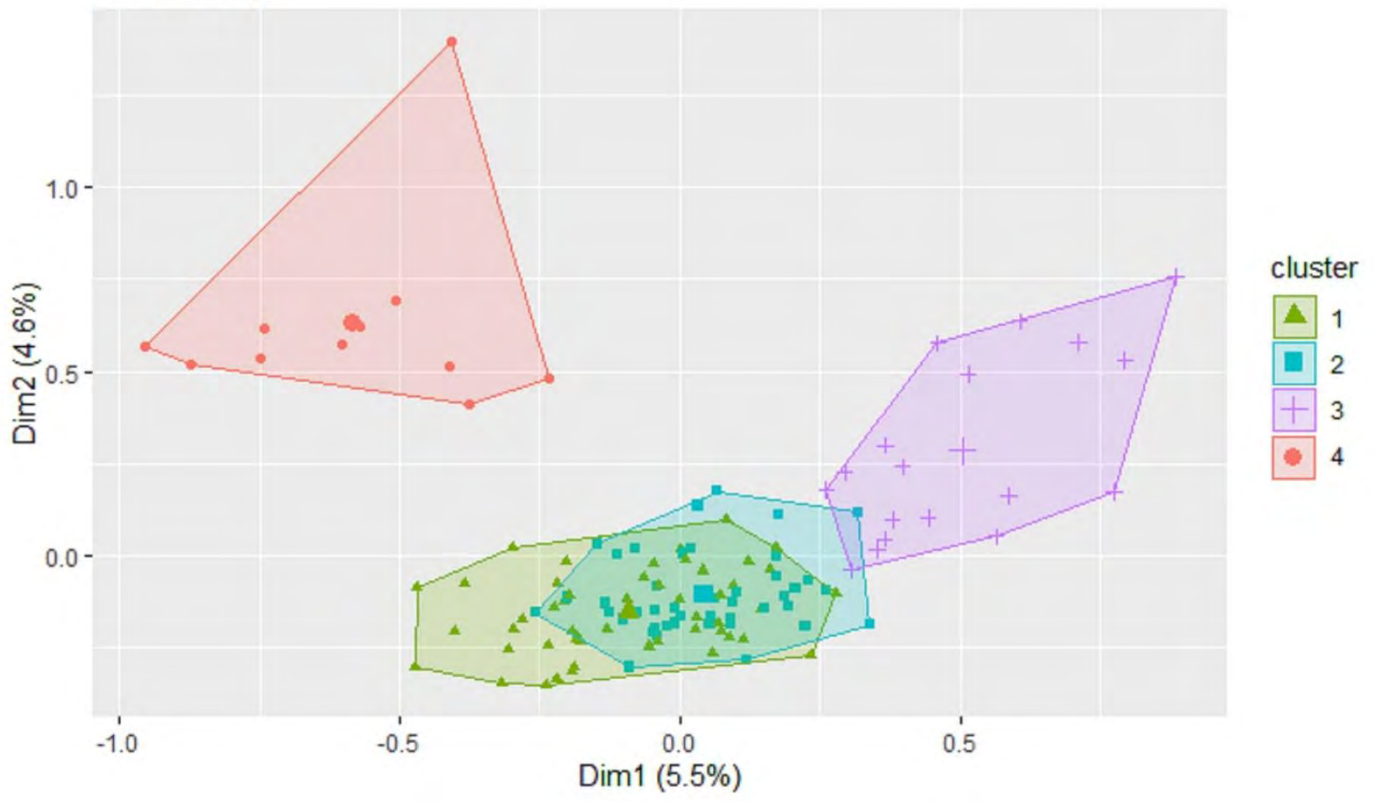


Fig. 5

REGENCY	<i>KECAMATAN</i>	<i>DESA</i>	No. of <i>dusun</i>			<i>Desa</i> surface area	<i>DUSUN</i> Sub-village	Number of	Surface area (km <sup>2</sup> )	Average area (S,km <sup>2</sup> )	No. of	Number of
	District NAME	Sub-district Name	RW**	RT**	Density	Location on volcano flank,	inhabitants per	Density of built	of <i>dusun</i> D= People	respondents,	interviews	
	No. inhabitants*	No. inhabitants*			inhab/km <sup>2</sup>	distance to vent (km)	<i>DUSUN</i>	blocks (inhab/km <sup>2</sup> )	density (inhab/km <sup>2</sup> )	221 households	per <i>Desa</i>	
MALANG	TIRTOYUDO 68,944	TAMANSATRYAN 7,135	4	8	36	14.40 km <sup>2</sup> 496 inhab/km <sup>2</sup>	Blubuk - Karangsono,	1,236	S= 0.064	S= 3.6 (average)	36	36
							West, 7.9–8.7 km		D= 709	D= 344		
							Pronojiwo Kota (town),		0.280	0.88 (average)		
		PRONOJIWO 7,896	7	14	41	6.20 1274	South, 10.2–11.5	1,082	0.280	0.88 (average)	12	
							Supit and Supit Timor,	1,485	0.198	0.88 (average)	22	
							South, 8.6–10.3	500	1,687	6		
	PRONOJIWO 36,606	SUPITURANG 5,854	4	6	17	8.29 706	Rowobaung, SSE	526	0.151	0.88 (average)	29	
							9.5 – 10.5	362	598			
							Sumbersari, SE	1,587	0.065	2.07 (average)	27	
	LUMAJANG	CANDIPURO 67,713	ORO-ORO OMBO 8,812	3	13	33	6.85 1286	9.3–10.4	1,796	767		
								Gumuk Mas, SE	1,983	0.125	2.07 (average)	26
								10.3–11.3	1,995	958	89	
SUMBERWULUH 10,787			10	10	43	17.60 613	Curah Koboan, SE	1,804	0.188	2.07 (average)	36	
							10.3–11.6	1,441	872			
							Oro-oro Ombo, SSE	2,938	0.267	2.28 (average)	3	
PASRUJAMBE 34,916	PASRUJAMBE 13,774	11	23	77	43.89 314	10.8–11.7	565	0.100	1.76 (average)	6		
						Kajar Kuning, SE	1,351	1.333	1.76 (average)	Officer		
						11.4–11.6	1,008	321				
SENDURO 50,387	SENDURO 7,735	5	21	58	6.22 1244	Sumberwuluh, SE	1,974	0.303	3.25 (average)	Officer		
						14.2– 16.7	892	2,634	608			
						Candipuro, ESE	1,338	0.077	3.99 (average)	16		
						Jabon, East	2,209	0.553	1.24 average	21		
						11.9–14.2	816	1,589	224			
						Tulungrejo, East	851	0.077	3.99 (average)	7		
						9.9–11.8	2,414	2,414	336			
						Sumbermuylyo,	1,584	1,584	1,782			
						East, 17.3–18.2			1.24 (average)	12		
						Juranglangak, East		0.282	658			
						18.2–19.4		960	1.24 (average)	18		
						Rekesan, East			687			
						19.4–20.3						

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<b>TOTAL</b> 258,566	69,849	S 116.45 km <sup>2</sup> D 600 on average	15 Dusun + 1 Desa (Candipuro)	20,243	0.28 average 1,397 average Total S 3.79 km <sup>2</sup>	S 2.07 average D 806 average Total S 33.2 km <sup>2</sup>	279	279
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**Table 1**



<b>Observations</b>	<b>Methods</b>	<b>Techniques</b>	<b>Purposes</b>
Set of variables from all surveys	Univariate Analysis UA	Frequency: histograms	To obtain the frequency of all categories of every variable
All couples of variables	Bivariate Analysis BA	Chi-square test	To identify dependence or independence between 2 variables
		Contingence tables: Burt Table	Allows to analyse the cross frequency between two variables
<p>- Illustrative variables entail all questions from Survey A (e.g., age groups and CSP)</p> <p>- Active variables include all questions from four Surveys</p>	Multiple Correspondence Analysis, MCA	Biplot graphics	To show links between categories of two variables
		Scree plot showing eigenvalues (with Benzécri's correction)	To define the number of dimensions (11) retaining most information
		Projection of observations (groups) in biplots	To show correlation between variables and dimensions 1 and 2
		Scatter plots	To show contributory categories that better describe each dimension and have similar behaviour
Explore the MCA outputs to elaborate on population categories and distinguish clusters	Hierarchical Agglomerative Clustering HAC	Dendrogram and Factor map	To define the suitable number of clusters (4)
		Chi-square test	To identify links between 81 variables, selecting 28 discriminant variables having a small p-value <0.05
		Frequency analysis of all survey datasets (replies to questions) for each cluster	To establish the socio-demographic, knowledge/perception and economic status for each cluster of people

**Table 2**

**SOCIO-DEMOGRAPHIC CHARACTERISTICS (Survey A, 279 respondents)**

Question	Answer			
<b>1. SOCIO-DEMOGRAPHIC CATEGORIES</b>				
Q2. Age group	5 to 18 years	19 to 30 years	31 to 59 years	> 60 years
Q3. Marital Status	Single	Married	Married	Widowed
<b>Sub-total</b>	<b>2.87%</b>	<b>19%</b>	<b>49.10%</b>	<b>3.23%</b>
Q4. Household: people total	Large family (≥ 5)	Medium size (3, 4 or 5)	Medium size (3 or 4))	Small family (1-2)
Q5. Household: family number	≥ 2	1	1	≤ 1
Q6. 0-14 years	≥ 1	≥ 1	≤ 1	0
Q7. 15-60 years	≥ 2	≤ 3	≤ 3	≤ 2
Q8. > 60 years	≤ 2	0	≤ 1	≤ 2
Q11. Working people number	≥ 2	≤ 2	≤ 2	≤ 1
<b>Sub-total</b>	<b>11.46%</b>	<b>30.47%</b>	<b>23.66%</b>	<b>6.81%</b>
Q9. Education level	High education	High school	Secondary school	Elementary school or no education
Q10. Socio-professional category	Profession requiring high education: teachers, lawyers, health workers, civil servants, administration	All kind of jobs: factory worker, transport/services, agriculture worker, teacher/lawyer, local administration and small business	Job requiring minimal education: small-income jobs, agriculture worker, housewife, student, factory worker and small business	Jobs that do not need education: small business, housewife, informal, agriculture worker; unemployed
Q12. Minimum salary threshold	Above	Above	Above or below	Below
<b>Sub-total</b>	<b>3.23%</b>	<b>12.54%</b>	<b>21.15%</b>	<b>27.24%</b>
<b>2. GEOGRAPHICAL ORIGIN AND ARRIVAL TIME IN THE AREA</b>				
Q14. Geographical origin of the respondent	Semeru	East Java/Semeru	Central/East Java/Semeru	Madura/Other
Q16. Father	Semeru/East Java	East Java/Semeru	Local origin or beyond East Java	Madura/Other
Q17. Mother	Semeru/East Java	East Java/Semeru	Local origin or beyond East Java	Madura Other
Q15. How long have you been living in the area?	> 50 years	20 – 50 years	2 -25 years	< 2 years / 2 – 25 years
<b>Sub-total</b>	<b>10.75%</b>	<b>24.73%</b>	<b>11.83%</b>	<b>5.38%</b>
<b>CLUSTERS (Frequency analysis)</b>				
A. Young and mature adults, independent and resource person, educated; local origin	B. Young, adult and older adults, independent and resource person, educated or not; local origin or beyond East Java	C. Young, young adults, without or low resource person, educated; local origin or beyond East Java	D. Adults and older adults, dependent on families, without or low resources, educated; local or beyond East Java origin	E. Adults and elderly, dependent on families, without or low resources, minimally or not educated; local or beyond East Java origin
<b>34.77%</b>	<b>5.73%</b>	<b>16.13%</b>	<b>2.87%</b>	<b>40.50%</b>

**Table 3**

**HAZARD KNOWLEDGE LEVEL (Survey B, 267 respondents)**

Question	Answer	Answer	Answer	Answer
<b>1. VOLCANO AND ERUPTION</b>				
Q1. Can you name the nearest volcano to your home?	Yes	Yes	Yes	No
Q2. Do you know what year this volcano last erupted?	Knows the date	Knows approximately the date	Does not know the date	Does not know the date
<b>Sub-total</b>	<b>Cohort 73 27.34 %</b>	<b>98 36.70 %</b>	<b>63 23.60 %</b>	<b>12 4.49 %</b>
<b>2. HAZARD-ZONE MAP</b>				
Q3. Is he/she able to read the hazard-zone map?	Yes	Yes	Yes or no	No
Q4. Can he/she locate his/her village?	Yes	Yes	Yes	No
Q5. Does he/she know the hazard-zone color meaning?	Knows colours and meaning	Knows colours	Does not know colours and meaning	Does not know colours and meaning
<b>Sub-total</b>	<b>Cohort 40 14.18 %</b>	<b>40 14.18 %</b>	<b>69 25.84 %</b>	<b>94 35.21 %</b>
<b>3. VOLCANIC PHENOMENA</b>				
Q6. Do you know what volcanic ash is?	Knows and has experienced it	Knows and has experienced it/Knows	Knows and has experienced it/Knows	Does not know
Q7. Do you know what a PDC "Awan panas" is?	Knows and has experienced it	Knows	Does not know	Does not know
Q8. Do you know what a lahar is?	Knows and has experienced it	Knows and has experienced it /Knows	Knows and has experienced it /Knows	Does not know
<b>Sub-total</b>	<b>Cohort 62 23.22 %</b>	<b>74 27.72 %</b>	<b>70 30.84 %</b>	<b>6 2.25 %</b>
<b>4. LAHAR OCCURRENCE AND IMPACT</b>				
Q9. Lahar occurrence estimate	Precisely	Approximately	Cannot say	Cannot say
Q10. Can you estimate the arrival time of a lahar to your village once it has been triggered on the mountain?	30-60 minutes/20-10 minutes	30-60 minutes /20-10 minutes	30-60 minutes /20-10 minutes	Below 10 minutes /Does not know
Q11. Do you know of any victims or/and injured people?	Knows number and names or approximately	Knows number and names or approximately	Knows approximately number	Does not know
<b>Sub-total</b>	<b>Cohort 42 15.61 %</b>	<b>37 13.86 %</b>	<b>22 8.24 %</b>	<b>25 9.36 %</b>
<b>5. ERUPTION AND LAHAR OCCURRENCE INTERVAL TIME</b>				
Q12. How long can a volcanic eruption from Semeru last?	More than one day	Few hour	Few hours	Does not know
Q13. How long can lahar occur after a volcanic eruption from Semeru?	Can happen without eruption/ Just after an eruption	Can happen without eruption	Just after an eruption/During the eruption	Does not know
<b>Sub-total</b>	<b>Cohort 30 11.24 %</b>	<b>83 31.09 %</b>	<b>53 19.85 %</b>	<b>9 3.37 %</b>
<b>LEVELS</b>				
<b>A. Very good knowledge</b>	<b>B. Good knowledge</b>	<b>C. Regular knowledge</b>	<b>D. Poor knowledge or un-awareness</b>	
<b>61 22.85 %</b>	<b>87 32.58 %</b>	<b>74 27.72 %</b>	<b>45</b>	<b>16.85 %</b>

**Table 4**

**LEVELS OF RISK PERCEPTION AND ASSOCIATED VARIABLES LEADING TO AWARENESS AND PREPAREDNESS (Survey C, 253 respondents and Survey D2, 227 respondents)**

Question	Answer	Answer	Answer	Answer
C.Q1+Q2+Q3+Q4+.In your daily life, do you feel worried or concerned about lahar, volcano or something else?	Other/none No No Other hazard	Other/none No Yes or no Daily hazard	Lahar/Volcano No Yes Daily hazard	Lahar/Volcano Yes Yes Volcano hazard
<b>Sub-total</b>	<b>Cohort 11 4.35 %</b>	<b>37 14.62 %</b>	<b>64 25.30 %</b>	<b>69 27.27 %</b>
D2.Q1. Do you participate in solidarity work?	Yes	Yes	Yes	No
D2.Q2. Do you participate in community service?	Yes	Yes	Yes or no	No
D2.Q4. Do you participate in another organization/association?	Yes	Yes or no	Yes or no	No
D2.Q3. Individualist behavior (keep to self)?	No	No	Yes	Yes
D2.Q5. Are you a leader of an association?	Yes	No	No	No
<b>Sub-total</b>	<b>Cohort 13 5.73 %</b>	<b>70 30.84 %</b>	<b>84 37.00 %</b>	<b>8 3.52 %</b>
C.Q5. Have you ever seen a lahar?	Yes	Yes	No	No
C.Q6. Have you ever seen a PDC?	Yes	No	Yes	No
<b>Sub-total</b>	<b>Cohort 120 47.43 %</b>	<b>97 38.34 %</b>	<b>4 1.58 %</b>	<b>23 9.09 %</b>
C. Q7. Have you ever been affected by a lahar (injured, flooded house, etc.)?	Never	Never	Never	Yes/Little
C.Q8. Do you feel that a lahar would hit you again?	Never or does not know	Never or does not know /Once	More than once or Once	More than once
C.Q9. Do you feel that a PDC would hit you again?	Never or does not know	Once	More than once or Once	More than once/ Never or does not know
<b>Sub-total</b>	<b>Cohort 99 39.13 %</b>	<b>24 9.49 %</b>	<b>37 14.62 %</b>	<b>21 8.30 %</b>
C.Q10. Do you know of anyone among your family or friends who has been affected by a lahar?	Yes	Yes	No	No
C.Q11. Do you know of anyone among your family or friends who has been affected by a PDC?	Yes	No	No	No
C.Q12. Did his/her stories have an effect on how you deem a lahar dangerous?	Yes	Yes/Little	Yes/Little	Never
C.Q21. How do you know a lahar, a PDC?	From experience, authorities and school	From experience, authorities and school	From all	From all
<b>Sub-total</b>	<b>Cohort 21 8.30 %</b>	<b>91 35.97 %</b>	<b>54 21.34 %</b>	<b>40 15.81 %</b>
C.Q19. Can you describe a lahar?	Yes	Yes	Little	Cannot
C.Q20. Can you describe a PDC?	Yes	Little/Cannot	Little/Cannot	Cannot
<b>Sub-total</b>	<b>Cohort 62 24.51 %</b>	<b>79 31.23 %</b>	<b>30 11.86 %</b>	<b>26 10.28 %</b>
C.Q18. Can you identify or discuss a particular lahar that you remember?	Yes	Yes	Little/ Never or does not	Never or does not
C.Q16. How long ago did this lahar occur?	One or 10 years	One or 10 years	Weeks, months/ One or 10 years	Weeks, months/ One or 10 years

C.Q17. How did you behave that day?	Evacuated or auto-evacuated to official shelter	Remained there but checked for advice with local authorities	Remained/ Evacuated or auto-evacuated	Did not move and did not know what to do
<b>Sub-total</b>	<b>Cohort 47 18.58 %</b>	<b>39 15.42 %</b>	<b>90 35.57 %</b>	<b>11 4.35 %</b>
C.Q23. Does a lahar call your attention?	Interesting	Interesting	More or less	No interest
C.Q24. Does a PDC call your attention?	Interesting/More or less	More or less	No interest	No interest
C.Q26+25. Do you like to observe a lahar from a safe distance?	Everything	Everything or some of the above phenomena	Everything or some of the above phenomena	Nothing or some of the above phenomena
	Scenery, noise, power and other	Scenery; noise and power	Scenery; noise and power	All
<b>Sub-total</b>	<b>Cohort 15 5.83 %</b>	<b>78 30.83 %</b>	<b>25 9.88 %</b>	<b>79 31.23 %</b>
C.Q27. What do you think about people crossing the river with motorbikes before the lahar has come to a stop?	Un-reasonable	Un-reasonable /Careless	Careless	Un-reasonable /Careless
C.Q28+30+31. Do you feel that such a phenomenon is so powerful than mankind cannot do anything about it?	Yes, but something can be made about it	No, too powerful	Cannot be overcome/Yes, but something can be made about it	Cannot be overcome
Do you feel self-confident in case of an eruption?	Very confident	Very or little confident	Very or little confident/Afraid	Little confident/Afraid
	Can overcome the consequences	Can overcome the consequences/it is difficult	Can overcome the consequences/it is difficult	It is impossible or difficult/Can overcome the consequences
<b>Sub-total</b>	<b>Cohort 18 7.11 %</b>	<b>36 14.23 %</b>	<b>66 26.09 %</b>	<b>45 17.79 %</b>
C.Q32. Will you comply with the evacuation order in any type of situation?	Shall	Shall	Sometime or in extreme events	Sometime or in extreme events/Never, or he first search for another solution
C.Q33+34. Whom do you receive warning messages from in case of lahar?	From all sources of available information	Person in charge	Person in charge	None, does not trust anyone
	TV, Smartphone/Radio/Stuff of government agencies	TV, Smartphone/Radio/Stuff of government agencies	TV, Smartphone /Stuff of government agencies or Word of mouth	Word of mouth/Other or does not know
C.Q35. Do you believe messages and/or do you try to check the content?	No, believes the authorities	No, believes the authorities /Try to check with neighbours	No, believes the authorities /Try to check with neighbours	Try to check with neighbours /Trusts none of them and does not check
<b>Sub-total</b>	<b>Cohort 6 2.37 %</b>	<b>77 30.43 %</b>	<b>37 14.62 %</b>	<b>10 3.95 %</b>
D2.Q10. Where from do you expect early warning?	Governmental agency/TV/radio/Smartphone"	Governmental agency	TV/radio/Smartphone"	Other/no warning at all
D2.Q11: Do you check upon warning?	Trusts, no need to check	Checks with many	Checks with neighbours or many	Unaware
<b>Sub-total</b>	<b>Cohort 54 27.79 %</b>	<b>82 36.12 %</b>	<b>41 18.06 %</b>	<b>6 2.64 %</b>
D2.Q12: How do you feel about the eruption?	Quiet	Quiet/Concerned	Afraid	Afraid/Traumatized
D2.Q13: How do you feel about the lahar?	Quiet	Concerned	Afraid/Quiet/Concerned	Afraid/Traumatized
D2.Q14: How do you feel about the awan panas?	Quiet/ Concerned	Concerned	Afraid/Quiet/Concerned	Afraid/Traumatized
<b>Sub-total</b>	<b>Cohort 49 21.59 %</b>	<b>16 7.05 %</b>	<b>89 39.21 %</b>	<b>32 14.10 %</b>
<b>LEVELS (Survey C)</b>				
<b>A. Aware and confident</b>	<b>B. Concerned about daily life</b>	<b>C. Concerned about volcano and warning</b>	<b>D. Unaware and/or distrustful</b>	
<b>Cohort 64 25.30 %</b>	<b>76 30.04 %</b>	<b>65 25.69 %</b>	<b>48 18.97 %</b>	
<b>LEVELS (Survey D2)</b>				
<b>A. Well prepared</b>	<b>B. Prepared</b>	<b>C. Regularly prepared</b>	<b>D. Ill-prepared</b>	
<b>Cohort 54 23.79 %</b>	<b>65 28.63 %</b>	<b>60 26.43 %</b>	<b>48 21.15 %</b>	

**Table 5**

**SOCIO-ECONOMIC CATEGORIES (Survey D1, 228 respondents)**

Question	Answer	Answer	Answer	Answer
Q2: How did you get the land?	Owns Built/purchased	Owns Inheritance from parents	Does not own Inheritance from parents	Does not own No inheritance, land or home donated
<b>Sub-total</b>	<b>Cohort 69 30.26 %</b>	<b>117 51.32 %</b>	<b>17 6.09 %</b>	<b>4 1.75 %</b>
Q5-Q9: Do you own a car, motorbike, TV, fridge, other electronic appliances?	All	All (except a car)	All (except a car & other electronic appliances)	Own motorbike and TV
<b>Sub-total</b>	<b>Cohort 13 5.70 %</b>	<b>25 10.96 %</b>	<b>52 22.81 %</b>	<b>67 29.39 %</b>
Q10-Q12: Do you own bovine + sheep + poultry?	All	All (except bovine)	Own some poultry	Does not own
<b>Sub-total</b>	<b>Cohort 10 4.39 %</b>	<b>66 28.95 %</b>	<b>71 31.14 %</b>	<b>47 20.61 %</b>
Q13: Is there a crop storage facility?	Yes	No	No	No
Q14: How many crops do you harvest?	Diversification	Diversification	No diversification	No diversification
Q15: Do you own a garden, land, tree plantation?	Yes	Yes	Yes	No
<b>Sub-total</b>	<b>Cohort 67 29.39 %</b>	<b>30 13.16 %</b>	<b>48 21.05 %</b>	<b>32 14.04 %</b>
Q16: What sort of trade do you make?	Both	Outside	Inside	No trade
Q17: Is your monthly income above or below the minimum salary threshold?	Above	Above	Below	Below
<b>Sub-total</b>	<b>Cohort 26 11.40 %</b>	<b>15 6.58 %</b>	<b>75 32.89 %</b>	<b>14 6.14 %</b>
Q18: Do you have access to evacuation facilities?	Very accessible	Accessible	Accessible/Little accessible	No accessible
Q19: Is there any civil protection work against volcanic phenomena?	Yes	Yes	No	No
Q20: Do you or does your family suffer from any personal, physical handicap, or economic hardship?	No	No	Yes	Yes and no
<b>Sub-total</b>	<b>Cohort 10 4.39 %</b>	<b>18 7.89 %</b>	<b>49 21.49 %</b>	<b>6 1.74 %</b>
Q21: Are you in debt?	No	No	Yes	Yes
Q22: Are you insured?	Yes	No	No	No
Q23: Do you benefit from microloans?	No	No	No	Yes
Q24: Can the family rebuild house in case of a disaster?	Yes	No	No	No
<b>Sub-total</b>	<b>Cohort 5 2.18 %</b>	<b>169 74.12 %</b>	<b>37 16.23 %</b>	<b>18 7.89 %</b>

**CATEGORIES**

**A. High income**

**Cohort 13 5.70 %**

**B. Middle income**

**65 28.51 %**

**C. Low income**

**100 43.86 %**

**D. Very low income**

**50 21.93 %**

**Table 6**

Variable	p value	Degree of freedom (df)
C.16 How long ago ?	6,45E-23	6
B.13 Potential lahar timing	1,07E-18	9
C.18 Impact of memory on behaviour	4,39E-14	6
C.19 Description of a lahar	4,49E-14	6
D2. 3 Individualist behaviour keep to self	9,13E-14	3
C.15 Records a particular lahar	3,72E-11	3
B.5 Area colour meaning	1,89E-10	6
D1.20 Handicap	2,37E-10	3
B.2 Semeru last eruption	3,03E-10	6
D2.2 Participate in <i>kerja bakti</i>	8,62E-10	3
B.9 Lahar occurrence estimate	3,6E-09	6
B.10 Estimated triggering time	4,44E-09	12
B.7 PDC	4,2E-08	6
<b>Block</b>	3,15E-07	12
D1. 19 Protection against volcanic phenomena shelter education program civil engineering measures	4,12E-07	0
C.17 Behaviour during this event	5,48E-07	3
C.8 Lahar can hit again	6,11E-07	6
C.25 likes observing a lahar or HCF	9,92E-07	6
C.9 Awan pas would hit again	1,26E-06	6
C.27 Opinion about other people s behaviour in case of flow	1,29E-06	6
C.5 Already saw a lahar	1,6E-06	3
C.30 Self confidence	2,28E-06	6
C.28 Can we overcome the phenomenon	2,12E-05	6
C.12 Effect of stories about lahar	2,15E-05	6
D1.13 Crop storage facility	3,76E-05	3
C.1 Category of concern	6,2E-05	6
C.33 Provenance of the message	6,29E-05	6
C.3 Personal or Family concern	9,65E-05	3
D1.10 Bovine cattle	9,65E-05	3
B.6 Volcanic ash	0,000144	6
C.29 Solution choice to overcome flow effects	0,000145	6
C.20 Description of a PDC	0,000152	6
B.1 Volcano name Semeru	0,000162	3
C.31 Estimate his/her capacity to overcome	0,000193	9
D2.11 Check upon warning or milling	0,000215	9
C.6 Already saw PDC	0,000263	3
D2.12 About eruption	0,000393	12
D2.8 Regional	0,000412	6
D2.4 Association member	0,000524	3
<b>Distance to river</b>	0,000616	6
C.34 Ranking used media	0,001213	9
C.35 Trust in messages milling	0,001278	6
B.12 Duration with respect to eruption	0,001549	6
D1.4 Type of job	0,00171	6
C.21 Origin of knowledge	0,002149	9
D2.9 Local	0,002175	6
A. Family number	0,002481	15
C.22 Lahar occurrence in the same place	0,002916	6
C.2 Related to Semeru	0,00317	3
C.4 Family s specific concern	0,003404	6
B.3 Map reading ability	0,0041	3

<b>C.10</b> Friends or relatives hit by lahar	0,004206	3
<b>D2.7</b> National	0,004504	6
<b>D1.1</b> Land/house owner	0,005882	3
<b>C.26</b> Specific interest in flow	0,007112	9
<b>B.8</b> Lahar	0,008771	6
<b>C.13</b> Traffic accident of family or friends	0,009702	3
<b>D2.10</b> Warning origin expectation	0,011787	9
<b>D1.21</b> Debt	0,013775	3
<b>C.7</b> Ever been affected by a lahar	0,023442	6
<b>C.14</b> Effect of accident on lahar danger perception	0,024865	9
<b>D1.2</b> How he she got the land	0,02638	6
<b>D2.6</b> Personal type of experience	0,038527	9
<b>D1.3</b> Family support	0,044518	12

**Table 7**



CLUSTER	1		2		3		4	
TOPICS, QUESTIONS AND ANSWERS	SOCIO-DEMOGRAPHIC CATEGORIES FROM SURVEY A							
<b>Q1.</b> Gender	Male	59.18%	Male	67.44%	Male	66.67%	Male	81.82%
<b>Q2.</b> Age group	31 to 59 years	55.10%	31 to 59 years	51.16%	19 to 30 years	38.89%	31 to 59 years	81.82%
	≥ 60 years	26.53%	≥ 60 years	23.26%	31 to 59 years	33.33%	19 to 30 years	18.18%
	19 to 30 years	16.33%	19 to 30 years	20.51%	≥ 60 years	22.22%		
<b>Q3.</b> Marital Status	Married	87.76%	Married	79.07%	Married	83.33%	Married	90.91%
<b>Q4.</b> Household: Total of people	4	30.61%	3 to 5	81.84%	2 to 5	88.89%	5	63.64%
	< 4	36.73%					< 5	36.36%
<b>Q5.</b> Household: Number of families	1	55.10%	1	97.67%	1	83.33%	1	73.73%
	1 to 2 (0 to 14 years)	67.35%	1 to 2 (0 to 14 years)	65.11%	1 to 2 (0 to 14 yr)	72.22%	≥ 1 (0 to 14 years)	90.91%
<b>Q6+7+8.</b> Household age group and people number	2 to 6 (15 to 60 years)	81.63%	2 to 3 (15 to 60 yrs)	67.40 %	1 to 2 (15 to 60 yr)	77.78%	2 to 4 (15 to 60 years)	100%
	0 (> 60 years)	55.10%	0 (> 60 years)	81.40 %	0 (> 60 yr)	66.67 %	0 (> 60 years)	90.91%
	Total: 1 to 8	100%	Total: 1 to 5	93.03 %	Total: 2 to 5	88.90%	Total: 4 to 5	81.80 %
<b>Q9.</b> Education level	Elementary school	46.94%	Elementary school	58.14%	Elementary school	44.44%	Elementary school	36.36%
	High school	24.49%	Secondary school	26.23%	Secondary school	22.22%	Secondary school	36.36%
	Agriculture, Housewife, Small Business, Administration, Small income jobs, Teacher/lawyer, Student, Retired, Transport/Services.		Agriculture, Housewife, Small Business, Small income jobs, Teacher/lawyer, Health worker, Lawyer, Student, Retired.		Agriculture, Housewife, Small Business, Administration, Small income jobs, Health worker, Student.		Agriculture, Housewife, Small Business, Administration, Several small income jobs, Teacher/lawyer.	

#### GEOGRAPHICAL ORIGIN AND ARRIVAL TIME IN THE AREA

<b>Q13.</b> Geographical origin of the respondent	Semeru	79.59%	Semeru	83.72%	Semeru	72.22%	Semeru	81.81%
	East Java	18.37%	East Java	13.95%	East Java	27.78%	East Java	18.18%
<b>Q20.</b> How long have you been living in the area?	25 to 50 years	57.14%	> 2 years	97.67%	25 to 50 years	44.44%	25 to 50 years	72.73%
	> 50 years	32.65%			5 to 25	33.33%		
					> 50 years	16.67%		

#### ADDITIONAL CHARACTERISTICS: PEI, GEOGRAPHICAL LOCATION AND ECONOMIC STATUS

<b>EIPN</b> (See Thouret et al., 2021, in review)	Residual	24.49%	Residual	27.90%	Residual	16.67%	Moderate	36.36%
	Low	10.20%	Low	9.30%	Low	5.56%	High	54.54%
	Moderate	4.00 %	Moderate	11.63%	Moderate	27.78%	Very high	9.09%
	High	18.37%	High	18.60%	High	11.10 %		
	Very high	42.86%	Very high	32.56%	Very high	33.33%		
<b>Distance to river</b> (ESD Table 1)	Mid	38.78%	Mid	44.19%	Far away	72.22%	Mid	72.73%
	Near	34.69%	Near	30.23%				
<b>Economic status</b> (Surveys D and E)	Middle income	38.78%	Low income	53.49%	Middle income	33.33%	Middle income	54.55%
	Low income	40.82%			Low income	44.44%		

CLUSTER	1		2		3		4	
<b>HAZARD KNOWLEDGE, FROM SURVEY B</b>								
<b>TOPICS, QUESTIONS AND ANSWERS</b>	<b>VOLCANO AND ERUPTION</b>							
Q1. Can you name the nearest volcano to your home?	Yes	97.96%	Yes	100%	Yes	72.22%	Yes	90.91%
Q2. Do you know what year this volcano last erupted?	Approximately	67.35%	Knows	60.64%	Does not know	61.11%	Knows	63.64%
<b>HAZARD-ZONE MAP</b>								
Q3. Is he/she able to read the hazard-zone map?	No	69.39%	No	74.42%	No	72.22%	Yes	81.82%
Q4. Can he/she locate his/her village?	Yes	61.22%	Yes	67.44%	No	55.56%	Yes	81.82%
Q5. Does he/she know the hazard-zone colour meaning?	Does not know	89.8%	Does not know	79.07%	Does not know	83.33%	Knows the colours and meaning	45.45%
<b>VOLCANIC PHENOMENA</b>								
Q6+7+8. Do you know what volcanic ashfall/PDC/Lahar is?	Knows and has experienced ashfall	95.92%	Knows and has experienced ashfall	79.07%	Knows and has experienced ashfall	72.22%	Knows and has experienced ashfall	72.73%
	Knows and has experienced a PDC	46.94%	Knows what a PDC is	53.49%	Does not know PDCs	77.78%	Knows and has experienced a PDC	72.73%
	Knows and has experienced a lahar	75.51%	Knows and has experienced a lahar Knows what a lahar is	48.84 % 48.84 %	Knows and has experienced a lahar Knows what a lahar is	44.44% 38.89%	Knows and has experienced a lahar	81.82%
<b>LAHAR OCCURRENCE AND IMPACT</b>								
Q9. Lahar occurrence estimate	Approximately Precisely	51.02% 32.65%	Precisely	83.7 %	Cannot say	50.00%	Approximately	63.64%
Q10. Can you estimate the arrival time of a lahar to your village once it has been triggered on the mountain?	30 to 60 minutes	59.18%	30 to 60 minutes	62.79%	Does not know	50.00%	10 to 30 minutes	81.82%
Q11. Do you know of any victims or/and injured people?	Does not know Approximately	34.69% 30.61%	Approximately Knows the number and names	37.21% 34.88%	Does not know	61.11%	Knows the number and names	63.64%
<b>ERUPTION AND LAHAR OCCURRENCE INTERVAL TIME</b>								
Q12. How long can a volcanic eruption from Semeru last?	A few hours	83.67%	A few hours	81.40%	A few hours More than one day	61.11% 22.22%	A few hours More than one day	36.36% 36.36%
Q13. How long can lahar occur after an eruption from Semeru?	Can happen without eruption	91.84%	Can happen without eruption Just after an eruption	67.44% 23.26%	Does not know Just after an eruption	61.11% 16.67%	Just after an eruption	100%

CLUSTER	1	2	3	4				
TOPICS, QUESTIONS AND ANSWERS	RISK PERCEPTION, AWARENESS AND PREPAREDNESS, FROM SURVEY C							
C.Q1+Q2+Q3+Q4+Q14. In your daily life, do you feel worried or concerned about lahar, volcano or something else?	Q1. Volcano	53.06%	Q1. Volcano	54.81%	Q1. Lahar	61.11%	Q1. Volcano	54.55%
	Q1. Lahar	44.90%	Q1. Lahar	34.88%	Q1. Other or none	33.33%	Q1. Other or none	36.36%
	Q2. Yes	57.14%	Q2. Yes	67.44%	Q2. No	83.33%	Q2. Yes	63.64%
	Q3. Yes	95.92%	Q3. Yes	97.67%	Q3. Yes	100%	Q3. Yes	63.64%
	Q4. Volcanic hazard	48.98%	Q4. Volcanic hazard	32.56%	Q4. Economy	77.78%	Q4. Volcanic hazard	81.82%
Q4. Economy	48.98%	Q4. Economy	67.44%					
D2. Q1+Q2+Q4. Do you participate in solidarity work, community service, another organization/association?	Q14. Yes	69.39%	Q14. Yes	67.44%	Q14. Yes	55.56%	Q14. Never	72.73%
	Q14. Never	22.45%	Q14. Never	25.58%	Q14. Never	38.89%	Q14. Yes	27.27%
	Q1. Yes	79.59%	Q1. Yes	83.72%	Q1. Yes	72.22%	Q1. No	54.55%
D2.Q3. Individualist behaviour (keep to self)?	Q2. Yes	97.96%	Q2. Yes	97.67%	Q2. Yes	100%	Q2. No	54.55%
	Q4. No	63.27%	Q4. Yes	74.42%	Q4. No	66.67%	Q4. Yes	72.73%
D2.Q5: Are you a leader of an association?	No	93.88%	Yes	88.37%	No	55.56%	Yes	63.64%
C.Q5+Q6+Q7. Have you ever seen a lahar or a PDC? Have you ever been affected by a lahar (injured, flooded house, etc.)?	No	97.96%	No	90.07%	No	94.44%	No	81.82%
	Q5. Yes	100%	Q5. Yes	97.67%	Q5. Yes	66.67%	Q5. Yes	100%
	Q6. Yes	73.47%	Q6. Yes	51.16%	Q6. No	83.33%	Q6. Yes	72.73%
C.Q8+Q9 Do you feel that a lahar or a PDC would hit you again?	Q7. No	69.39%	Q7. No	86.05%	Q7. No	94.44%	Q7. No	45.45%
	Q8. Does not know	32.65%	Q8. Does not know	81.40%	Q8. Does not know	88.89%	Q8. Does not know	63.64%
	Q8. More than once	51.02%	Q9. Does not know	67.44%	Q9. Does not know	83.33%	Q9. Does not know	90.91%
D2.Q6. Type of experience with respect to PDC or lahar?	Q9. More than once	42.86%	Q9. More than once	32.56%				
	Direct	44.90%	Direct	39.59%	Direct	22.22%	Direct	81.82%
C.Q10+11. Do you know of anyone among your family or friends who has been affected by a lahar or a PDC?	Indirect	24.49%	Vicarious	32.56%	Vicarious	38.89%		
	Q10. Yes	53.06%	Q10. Yes	46.51%	Q10. No	66.67%	Q10. Yes	100%
	Q10. No	46.93%	Q10. No	53.49%	Q11. No	94.44%	Q11. No	72.73%
C.Q12+13. Did his/her stories have an effect on how you deem a lahar dangerous?	Q11. No	71.43%	Q11. No	88.37%	Q12. Never	66.67%	Q12. Yes	72.73%
	Q12. Yes	73.47%	Q12. Yes	83.72%	Q12. Yes	27.78%	Q13. Yes	72.73%
C.Q17. How did you behave that day?	Q13. Yes	89.80%	Q13. Yes	65.12%	Q13. Yes	55.56%		
	Remained there but searched for order/advice	65.31%	Remained there but searched for order/advice	23.26%	Did not move and did not know what to do	33.33%	Remained there but searched for order/advice	100%
	Evacuated or auto-evacuated	22.45%	Evacuated or auto-evacuated	65.12%	Evacuated or auto-evacuated	44.44%		

C.Q19+20+22. Can you describe a lahar and a PDC?	Q19. Yes	83.67%	Q19. Yes	97.67%	Q19. Cannot Q19. Little	50.00% 33.33%	Q19. Yes	100%
	Q20. Yes Q20. Little	34.69% 32.65%	Q20. Yes Q20. Cannot	34.88% 58.14%	Q20. Cannot	83.33%	Q20. Yes Q20. Cannot	63.64% 27.27%
	Q22. Any rainy season	87.76%	Q22. Any rainy season	95.3 %	Q22. Any rainy season Q22. Does not know	61.11 % 38.89%	Q22. Any rainy season	100%
C.Q15. Can you identify or discuss a particular lahar that you remember?	Yes	91.84%	Yes	95.35%	No	72.22%	Yes	100%
C.Q16. How long ago did this lahar occur?	10 years One year	63.27% 36.73%	10 years One year	53.49% 44.19%	10 years	88.89%	Weeks, months	100%
C.Q21. How do you know a lahar, a PDC?	From experience From school or authorities	75.51 % 12.24 %	From experience From school or authorities	44.19 % 41.86%	From experience From school or authorities	33.33 % 38.89 %	From experience From school or authorities	63.64 % 27.27 %
C.Q18. Do you feel that your event memory can influence how to behave (e.g., running away or being evacuated)?	Yes	79.59%	Yes	81.4%	Never or does not know Little	50.00% 33.33%	Never or does not know	100%
C.Q23+24. Does a lahar or a PDC call your attention?	Q23. Interesting Q23. No interest	44.9% 30.61%	Q23. Interesting Q23. No interest	46.51% 30.23%	Q23. Interesting Q23. No interest	50% 44.44%	Q23. Interesting Q23. No interest	72.73% 18.18%
	Q24. No interest	85.71%	Q24. No interest	90.7%	Q24. No interest	94.44%	Q24. Interesting Q24. No interest	27.27% 63.64%
C.Q26+25. Do you like to observe a lahar/HCF from a safe distance?	Q25. Everything Q25. Some of the above phenomena	42.86% 51.02%	Q25. Everything Q25. Some of the quoted phenomena	36.88% 60.47%	Q25. Everything Q25. Nothing	27.78% 55.56%	Q25. Everything Q25. Some of the quoted phenomena	36.36% 63.64%
	Q26. Scenery Q26. Noise Q26. Other	34.69% 42.86% 12.24%	Q26. Scenery Q26. Power Q26. Noise	37.21% 20.93% 41.86%	Q26. Scenery Q26. Power Q26. Noise	22.22% 22.22 % 44.44%	Q26. Scenery	90.91%
	C.Q27. What do you think about people crossing the river with motorbikes before the lahar has come to a stop?	Careless Un-reasonable	32.65% 67.35%	Careless Un-reasonable	62.79% 32.56%	Careless Un-reasonable	50% 50%	Careless No point of view
C.Q28+29+30+31. Do you feel that such a phenomenon is so powerful than mankind cannot do anything about it? Do you feel self-confident in case of an eruption?	Q28. Can never be overcome Q28. No, too powerful Q28. Yes, but something can be made about the phenomenon	38.78% 32.65% 28.57%	Q28. Can never be overcome Q28. No, too powerful Q28. Yes, but something can be made about the phenomenon	58.14% 25.58% 16.28%	Q28. Can never be overcome Q28. No, too powerful Q28. Yes, but something can be made about the phenomenon	33.33% 33.33% 33.33%	Q28. Yes, but something can be made about the phenomenon	100%

	Q29. Prevention and evacuation Q29. No solution exists	59.18% 36.73%	Q29. Prevention and evacuation	95.35%	Q29. Prevention and evacuation Q29. No solution exists	66.67% 22.22%	Q29. Prevention and evacuation Q29. Protection work	81.82% 18.18%
	Q30. Very confident Q30. Afraid	79.59% 10.20%	Q30. Very confident Q30. Afraid	25.58% 67.44%	Q30. Very confident Q30. Afraid	66.67% 22.22%	Q30. Very confident Q30. Afraid	45.45% 36.36%
	Q31. Can overcome the consequences Q31. It is difficult	63.27% 34.69%	Q31. Can overcome the consequences	81.40%	Q31. Can overcome the consequences Q31. It is difficult Q31. It is impossible	27.78% 33.33% 22.22%	Q31. Can overcome the consequences Q31. It is difficult	54.55% 36.36%
C.Q32. Will you comply with the evacuation order in any type of situation?	I shall abide by the orders Sometime or in extreme events	69.39% 22.45%	I shall abide by the orders Sometime or in extreme events	58.14% 39.53%	I shall abide by the orders Sometime or in extreme events	61.11% 22.22%	I shall abide by the orders Sometime or in extreme events	72.73% 18.18%
C.Q33+34. Whom do you receive warning messages from in case of lahar?	Q33. Person in charge Q33. None or does not trust anyone	14.29% 73.47%	Q33. Person in charge Q33. All of them	95.35% 4.65%	Q33. Person in charge Q33. None or does not trust anyone	88.89% 11.11%	Q33. Person in charge Q33. None or does not trust anyone	36.36% 54.55%
	Q34. Staff of disaster risk management agency	85.71 %	Q34. Word of mouth Q34. Staff of disaster risk management agency	13.95% 72.09%	Q34. Word of mouth Q34. Staff of government agencies	33.33 % 50.00%	Q34. Word of mouth Q34. Staff of disaster risk management agency	45.45% 54.55%
C.Q35. Do you believe messages and/or do you try to check the content?	Believe the authorities Check with my neighbours	32.65% 65.31%	Check with my neighbours	76.74%	Check with my neighbours	77.78%	Believe the authorities	72.73%
D2.Q10. Where from do you expect early warning?	Governmental agency Smartphone	65.31% 26.53%	Governmental agency Smartphone	72.09% 20.93%	Governmental agency Smartphone other/no warning at all	55.56% 16.67% 16.67%	Governmental agency	81.82%
D2.Q11: Do you check upon warning?	Check with many Trust, no need to check	69.39% 18.37%	Check with many With neighbours	65.12% 23.36%	Check with many With neighbours Trust, no need to check	38.89 % 27.78 % 22.22 %	Trust, no need to check	72.73%
D2.Q12: How do you feel (quiet, concerned, afraid) about the volcano, PDC, lahar?	Concerned (volcano) Afraid (volcano) Quiet (volcano) Concerned (lahar) Quiet (lahar) Afraid (PDC) Quiet (PDC)	28.57% 30.61% 38.78% 26.53% 55.10% 53.06% 28.37%	Quiet (volcano) Concerned (lahar) Afraid (lahar) Quiet (lahar) Concerned (PDC) Afraid (PDC)	76.74% 25.58% 34.88% 39.53% 20.93% 58.14%	Afraid (volcano) Quiet (volcano) Afraid (lahar) Quiet (lahar) Afraid (PDC) Quiet (PDC)	33.33% 50.00% 22.22% 66.67% 55.56% 33.33%	Concerned (volcano) Afraid (volcano) Afraid (lahar) Quiet (lahar) Concerned (PDC) Afraid (PDC)	54.55% 27.27% 63.64% 18.18% 54.55% 27.27%

CLUSTER	1		2		3		4	
TOPICS, QUESTIONS AND ANSWERS	SOCIO-ECONOMIC CATEGORIES, FROM SURVEYS D AND E							
Q1: Do you own the house?	Yes	97.96%	Yes	81.84%	Yes	72.22%	Yes	100%
Q2: How did you get the land?	Inheritance/from parents	75.51%	Inheritance/from parents	60.47%	Inheritance/from parents	55.56%	Inheritance/from parents	63.64%
	Built/purchased	24.49%	Built/purchased	39.53%	Built/purchased	33.33%	Built/purchased	36.36%
Q4: Types of livelihoods and profession	Informal/Independent	75.51%	Business sale Informal/Independent	53.49%	Official salary; Informal/Independent	22.22%	Business sale Informal/Independent	45.45%
				34.88%		61.11%		45.45%
Q3: How many people contribute to the family resources?	1 to 2	85.71%	1 to 3	88.37%	1	72.22%	1 to 3	90.90%
Q5+Q6+Q7+Q8+Q9: Do you own a car, motorbike, TV, fridge, other electronic appliances?	No car	77.55%	No car	88.37%	No car	83.33%	No car	81.82%
	Yes, motorbike	93.88%	Yes, motorbike	90.70%	Yes, motorbike	88.89%	Yes, motorbike	100%
	Yes, TV	95.92%	Yes, TV	93.02%	Yes, TV	100%	Yes, TV	100%
	Yes, refrigerator	59.18%	Yes, refrigerator	51.16%	No refrigerator	66.67%	No, refrigerator	72.73%
	No other	71.43%	No other	69.77%	No other	77.78%	No other	81.82%
Q10+Q11+Q12: Do you own bovine + sheep + poultry?	No bovine cattle	95.92%	No bovine cattle	97.67%	No bovine cattle	100%	No bovine cattle	63.64%
	No sheep	63.27%	No sheep	55.81%	Yes, sheep	61.11%	Yes, sheep	54.55%
	Yes, poultry	75.51%	Yes, poultry	69.77%	Yes, poultry	72.22%	Yes, poultry	81.82%
Q13 Is there a crop storage facility?	No	81.63%	Yes	60.47%	No	72.20%	Yes	72.73%
Q14: How many crops do you harvest?	No diversification	53.06%	No diversification	67.44%	No diversification	66.67%	Diversification	72.73%
Q15: Do you own a garden, land, tree plantation?	Yes	85.71%	Yes	76.74%	Yes	83.33%	Yes	100%
Q16: What sort of trade do you make?	Both	42.86%	Inside Desa	62.79%	Inside Desa	61.11%	Outside Desa	27.27%
	Inside Desa	48.98%	Outside Desa	18.60%	Both	27.78%	Inside Desa	36.36%
							Both	27.27%
Q17: Is your monthly income above or below minimum salary threshold?	Below minimum	67.35%	Below minimum	76.74%	Below minimum	61.11%	Below minimum	54.55%
Q18: Do you have access to evacuation facilities?	Very accessible	69.39%	Very accessible	53.49%	Very accessible	38.89%	Very accessible	36.36%
			Accessible	32.56%	Accessible	38.89%	Little accessible	36.36%
Q19: Is there any civil protection work against volcanic phenomena?	No	91.84%	Yes	62.79%	No	72.22%	Yes	54.55%

Q20: Do you or does your family suffer from any personal, physical handicap economic hardship?	No	77.55 %	Yes	88.37 %	Yes	55.56 %	No	90.91%
Q21: Are you in debt?	No	71.43 %	Yes	60.47%	Yes	55.56%	No	63.64%
Q22: Are you insured?	No	69.39 %	No	58.14%	No	66.67%	No	90.91%
Q23: Do you benefit from microloans?	No	51.02 %	No	69.77%	No	77.78%	No	72.73%
Q24: Can the family rebuild house in case of a disaster?	No	73.47 %	No	76.74%	No	66.67%	No	63.64%

CLUSTER	1	2	3	4
<b>TOTAL FROM ALL SURVEYS A to E</b>	<b>40.50%</b>	<b>35.54%</b>	<b>14.88%</b>	<b>9.09%</b>

**Table 8**

<b><i>Volcano constraints and social disadvantages</i></b>	<b>Environmental and historical advantages</b>	<b>Adjustment and recovery from loss</b>	<b><i>Limitations to adjustment and coping</i></b>
Population growth rate 1.50% High rural density Minimal education, illiteracy rate Small number of health centres Disease spread in remote areas	Decline of population growth over the past 20 years, but 50% are young people <25 years Family planning; improving school education Diversity of crops including rice support dense population	Demographic robustness from high proportion of young and mature adults Improving health network	Health system must be improved in remote areas Access ways to <i>dusun</i> located high on volcano slopes must be improved
Multi and chronic hazards, variable in space and time	Pre-disaster social context is prepared due to persistent threats and chronic increase in activity Geographical location of 'old' <i>dusun</i> on ridges and high terraces away from valley channels	<i>Modify the effect of hazard*</i> Protection is not widespread, but has improved against lahars (dykes, check dams across main rivers)	Civil defense works are not well maintained and have become buried or damaged Old (Dutch) high platforms for evacuation are not maintained and became too small long ago
Variability of climate over the past 25 years or so Dense rainforest above 1300-1500 m asl	Available land and water, nutrient supply from recurrent ashfall to soil Warm temperature, high rainfall in equatorial lowlands, diversity on subequatorial mountain Available water, rivers and springs	Capitilizing on new opportunities help eschew climate adversities	Long-term planning or short-term policy have not been implemented to face the effects of climate change Annual variability in rainfall, temperature. Inter-annual variability in primary productivity
Limited land above 1500 m asl <i>Dusuns</i> encroach on valley banks Workers extracting material in channels, laborers in paddy terraces on low valley terraces	Access to land at mid-altitude slopes before Independence, and jobs in Dutch plantations (coffee, tea) Pioneer front between 1945 and 1980 Average primary productivity	Land cost remains low except near and inside urban areas	Competition for land in past pioneer areas Expansion of urban areas at the expense of farmland due to high density and population growth
Daily life hardships Limited access to infrastructure (paved road, train, electricity, telecommunication) Limited access to health in <i>dusun</i>	Traditional livelihood based on a variety of crops and diversity of ecological belts Agriculture output trade inside and outside <i>dusun</i> Agroforestry has been developed a few decades ago	Incomplete but improving <i>plan for loss*</i> Hazard-zone and contingency map Observers, rescue and relief teams ( <i>dusun</i> ) Early warning: radio network for lahars Storage capacity, a few shelters	Volcano monitoring: only one Observatory, but emergency evacuation plans for large volcanic eruptions Poorly indicated or old warning signs near active rivers. No zoning code
Limited resources in remote areas (high on volcano ridges) and/or in pioneering front (near active valley channels)	Wet rice cultivation supports high rural density (two harvests per year) combined with fruit trees and vegetables in lowlands <700 m. Advantage: permanent income source	Easy to clean land and recover plants from temporary loss, except along active rivers in case of destructive lahars and PDCs	Adversity in pioneer areas encroaching higher slopes facing persistent volcano activity Coarse deposits uneasy to use for crops, but few tree species (teak, sengon) may quickly grow
Medium-high social vulnerability High % of dependent people: children <14 years, elderly people >60 yr; >50% informal workforce	Solidarity network Charity associations	<i>Share and bear the loss*</i> : incomplete Insurance only for high-income people and elderly people Micro-loans and debt (inflation rate 7%/yr)	Poor to regular building performance. No building retrofitting, no resettlement No rehabilitation policy Limited access to credit

**Table 9**



<b>Factors of risk tolerance and resilience</b>	<b><i>Caveats and hindrances</i></b>	<b>Ability to balance livelihood and assets with chronic risk</b>
1. Attachment to place Majority of respondents were born around Semeru or in East Java.	Grand-parents migrated from Madura and the rest of Java. c. 22% of the population without hazard knowledge or experience arrived over the past 25 years	Majority of villagers were born on and around Semeru
2. Direct and individual experience based on past events (extended on lahars), combined with indirect and vicarious experiences	Much less experience in case of PDCs Experience on flow events not taught at school Uneven education degree, mostly elementary school, less secondary school, rare University students	Long-term dynamics of vulnerability varying in space and time: Contrasted exposure and vulnerability between traditional <i>dusun</i> (away from trade circuits) and towns or cities
3. Hazard knowledge gained from experience, school, local authorities, BNPB staff, relatives and neighbours	Widespread and uneven knowledge: high on lahars and tephra fall, but low on PDCs and impacts	Indirect and vicarious experience, school education for youngsters, disaster risk management staff all contribute to improve knowledge
4. Specific pre-disaster socio-cultural context around a persistently active volcano: Uneven risk perception and mixed feelings do not lead to widespread, sensible preparedness Shared awareness but does not imply preparedness Empowerment and self-efficacy	Contrasted and mostly regular risk perception False security due to Civil protection works Afraid of lahars, less afraid of volcano and PDCs Optimistic views and anchoring (mostly men) One third of the population without empowerment At least 15% people are unaware	Risk perception and feelings are contrasted and uneven Awareness is shared among leaders, officials, teachers, health and BNPB staff, but less among stakeholders and villagers The majority of the respondents declare they are able to overcome consequences
5. Sustainable livelihood and belongings	Low-income households prevail Major proportion of informal, un-protected, and un-skilled workforce	Assets: diversity of small-income jobs and animal husbandry Devastated areas recolonized within 15-20 years (plantations) Many shops in <i>dusun</i> (helping housewife income)
6. Alternative resources improve diversity of incomes: change in strategy for production and trade, fruit exportation, timber wood, material extraction in active rivers. Temporary migration across and beyond Java. Tourism: Hindu temples, road to Semeru-Tengger, natural attractions (waterfalls), homestays	Mobility and temporary migrations: disequilibrium in families Money transfer from abroad lead to inequities  Environmental issues about tourism	The potential for direct access to alternative resources through storage and/or mobility will generally need to be supplemented by exchange, redistribution and refuging.  Speed and direction of recovery (resilience) depend on robustness of population, alternatives, and available options
7. Social capital, social links, community bondedness	Spatial extent and strength of reciprocal social networks maintain social fabric Social links, but decreases amongst youngsters and people in towns	Diversity of traditional associations Sense of community helps balance low perception and mistrust Around Semeru where the impact is recurrent, the size and strength of social links is a critical component of resilience.
8. Culture beliefs and rituals	Modern life driving cultural changes among young people and in towns. Rituals are not declared.	Respect for Mother Nature, including volcano harm and benefits Risk culture is kept alive under the Muslim religion
9. Governance and social/political setting	Social and economic inequality Lack of investment for risk reduction in remote areas Rampant corruption among administration	New national government policy to develop infrastructure, health system, and new economic alternatives Globalization and 2020-2021 pandemic slow down the process

**Table 10**

## **ESD Text 1: List of questions per survey**

### **Survey A**

- Q1. Gender
- Q2. Age group
- Q3. Marital Status
- Q4. Household: Total of people
- Q5. Household: Number of families
- Q6. Household age group 1: 0-14 years
- Q7. Household age group 2: 15-60 years
- Q8. Household age group 3: >60 years
- Q9. Education level
- Q10. Socio-professional categories
- Q11. Number of people bringing resources to household
- Q12. Minimum salary threshold
- Q13. Geographical origin of the respondent
- Q14. Geographical origin of the father
- Q15. Geographical origin of the mother
- Q16. Geographical origin of the grandmother
- Q17. Geographical origin of the grandfather
- Q18. Geographical origin of the great-grandmother
- Q19. Geographical origin of the great-grandfather
- Q20. Time living in the area
- Q21. How long have your ancestors lived in the area?

### **Survey B**

- Q1. Can you name the nearest volcano to your home?
- Q2. Do you know what year this volcano last erupted?
- Q3. Is he/she able to read the hazard-zone map?
- Q4. Can he/she locate his/her village?
- Q5. Does he/she know the hazard-zone color meaning?
- Q6. Do you know what volcanic ash is?
- Q7. Do you know what a PDC is?
- Q8. Do you know what a lahar is?
- Q9. Lahar occurrence estimate
- Q10. Can you estimate the arrival time of a lahar to your village once it has been triggered on the mountain?
- Q11. Do you know of any victims or/and injured people?
- Q12. How long can a volcanic eruption from Semeru last?
- Q13. How long can lahar occur after a volcanic eruption from Semeru?

### **Survey C**

- Q1. In your daily life, do you feel worried or concerned about: volcano, lahar, other?
- Q2. Any concern related to Semeru?

- Q3. Are you concerned about you and/or your family daily life?
- Q4. If yes, what are you concerned about?
- Q5. Have you ever seen a lahar?
- Q6. Have you ever seen a PDC?
- Q7. Have you ever been affected by a lahar (injury, flooded house, etc.)?
- Q8. Do you feel that a lahar would hit you again?
- Q9. Do you feel that a PDC would hit you again?
- Q10. Do you know of anyone among your family or friends who has been affected by a lahar?
- Q11. Do you know of anyone among your family or friends who has been affected by a PDC?
- Q12. Did his/her stories have an effect on how you deem a lahar dangerous?
- Q13. Do you know of anyone who had a car or motorbike accident over the past year?
- Q14. Do you feel worried or scared about such accidents, and more than lahars?
- Q15. Can you identify or discuss a particular lahar that you remember?
- Q16. How long ago did this lahar occur?
- Q17. How did you behave that day?
- Q18. Do you feel that this memory can influence how to behave (e.g., running away or being evacuated)?
- Q19. Can you describe a PDC?
- Q20. Can you describe a lahar?
- Q21. How do you know lahars, PDCs?
- Q22. How long from now do you estimate that a lahar may occur at the same place?
- Q23. Does a lahar call your attention?
- Q24. Does a PDC call your attention?
- Q25. Do you like to observe a lahar from a safe distance?
- Q26. What attracts you the most?
- Q27. What do you think about people crossing the river with motorbikes before the lahar has come to a stop?
- Q28. Do you feel that such a phenomenon is so powerful than mankind cannot do anything about it?
- Q29. How do you think that the phenomenon or its effects can be overcome?
- Q30. Do you feel self-confident in case of an eruption?
- Q31. Do you think you are empowered to overcome the consequences?
- Q32. Will you comply with the evacuation order in any type of situation?
- Q33. Whom do you receive warning messages from in case of lahar?
- Q34. In which one do you have more confidence?
- Q35. Do you believe messages and/or do you try to check the content?
- Q36. Do you follow any rituals?

### **Survey D1**

- Q1. Do you own the house?
- Q2. How did you get the land?
- Q3. How many people contribute to the family resources?
- Q4. What kind of livelihood?
- Q5. Do you own a car?
- Q6. Do you own a motorbike?

- Q7. Do you own a TV?
- Q8. Do you own a fridge?
- Q9. Do you own other electronic appliances?
- Q10. Do you own bovine?
- Q11. Do you own sheep?
- Q12. Do you own poultry?
- Q13. Is there a crop storage facility?
- Q14. How many crops do you harvest?
- Q15. Do you own a garden, land, tree forest?
- Q16: What kind of economic exchange?
- Q17. Is your monthly income above or below the minimum salary threshold?
- Q18. Do you have access to evacuation facilities?
- Q19. Is there any civil protection work against volcanic phenomena?
- Q20. Do you or does your family suffer from any handicap?
- Q21. Are you in debt?
- Q22. Are you insured?
- Q23. Do you benefit from microloans?
- Q24. Have you ever been evacuated?
- Q25. Can the family rebuild house in case of a disaster?
- Q26. Structural typology of the house (see Survey E)
- Q27. Physical vulnerability of the house (see Survey E)

### **Survey D2**

- Q1. Do you belong to other organizations than solidarity work?
- Q2. Do you participate in solidarity work or community service?
- Q3. Individualist behavior (keep to self)?
- Q4: Are you a member of any association?
- Q5: Are you a leader of any association?
- Q6. Type of personal experience toward PDC or lahar?
- Q7. Appreciation of government help for preparedness at national level
- Q8. Appreciation of government help for preparedness at regional level
- Q9. Appreciation of government help for preparedness at local level
- Q10. Where from do you expect early warning?
- Q11: Do you check upon warning or milling?
- Q12: How do you feel about the volcano?
- Q13: How do you feel about lahars?
- Q14: How do you feel about PDCs

## ESD Text 2. Results from Surveys A, B, and C+D2

### Survey A

Socio-demographic characteristics obtained from survey A, and compared to data nationwide (Siagian et al., 2013; BPS, 2017), may enhance or diminish the adaptive capacity to chronic risk (Fig. 4):

1. The proportion of children <14 years and elderly people > 60 years, in contrast to the proportion of young and mature adults (15-59 years), is one factor diminishing adaptive capacity (ESD Fig. 5, graphs 'g'1-4). The proportion of children <14 years (24%) is comparable nationwide (26%), while the proportion of elderly people >60 years (12%) is double that of Indonesia (6.10%). One or two children <14 years are present in 70% of households around Semeru, but elderly people >60 years are less numerous. The majority of households (54%) host one couple with two children, living with at least one grandparent under the same roof.
2. Illiterate villagers (10%) around Semeru exceed the proportion nationwide (4%), while only 5% around Semeru have attended university, compared to 11% nationwide. Both parameters contribute to relatively high social vulnerability (Siagian et al., 2013, although illiteracy has receded over the past 20 years nationwide in particular for children and young adults (4.5%). Less than half of villagers (43%) around Semeru received elementary education, but almost 42% attended secondary or high school (ESD Fig. 5, g5).
3. Informal jobs, a source of economic inequality, prevail in *dusun* and small towns. Socio-professional categories reveal that many villagers hold two jobs, although one is informal or provides a meager income: official employees represent only 10% of our respondents, while 54% are independent workers, among them 30% are farm workers and another 32% work in, or own, a small business (ESD Fig. 5, g6). One man per household on average has two jobs in *dusun* close to active rivers, where they extract material or drive trucks in addition to farm and husbandry. Most women are housewives, and many own one small shop in c. 15% of the *dusun* houses, compared to 4.5% nationwide.
4. Knowing the origin of the population living on Semeru's slopes and the ancestor arrival time allows us to gauge whether or not long experience in at-risk areas or attachment to place has enabled people to tolerate persistent volcanic threats. Almost half (47%) of the respondents were born around Semeru, but this proportion increases to c. 56% if we also consider East Java for birth place (ESD Fig. 5, g7). However, Madura, an Island 105 km from

Semeru, North of Surabaya, is the second origin for over one third of the respondents; out-migration from Madura has been a continuous process due to chronic unemployment and poverty, limited soil resource, and social-religious conflicts. Madurese migrants joined the agricultural pioneer front and Dutch plantations on mid-altitude slopes of Semeru between 1945 and 1985. Semeru and East Java still represent the birth origin for 79% of respondent parents, but the Island of Madura becomes the third birthplace for all household members (g8-11) and decreases amongst ancestors (g12-13). Supporting this trend, as many as 53% people have been living on Semeru volcano between 25 to 50 years, while c. 26% of the respondents resided more than 50 years on the volcano slopes and mostly in the same village (ESD Fig. 5 g14-15). This is correlated with about 39% of ancestors who have lived around Semeru for 50 to >100 years, although ancestor and respondent memory may be biased (c. 44% “no answer”). A substantial 22% of the villagers migrated here from other provinces of Java and Madura over the past 25 years, often with limited knowledge of volcanic threats.

## **Survey B**

Key results from Survey B, related to hazard knowledge, are summarized below:

1. Basic knowledge about Semeru is widely shared, with almost 89% of the respondents identifying their closest volcano and two-thirds the year of its last eruption (ESD Fig. 6, g1-2).
2. The official hazard-zone map (scale 1:100,000, Bronto et al., 1969) was shown to all respondents with the aim of evaluating to which extent volcanic hazards and colour-coded hazard zones were understood, and whether the map was used as a communication tool for villagers near active valleys (ESD Fig. 6, g3-5). The majority of respondents (c. 55%) cannot read the hazard-zone map, which is not displayed in schools. Knowledge is insufficient based on education, as basic elements of eruptive activity, volcanic hazards and impacts are not taught across East Java. A majority of people (>56%) were able to approximately locate their village on the map, but almost 77% did not understand the meaning of the hazard zones. Communication on hazard-zones appears to have been poorly disseminated and the relatively poor understanding of hazard zones does not match the work lead by the disaster risk management agency (BNPB), whose purpose is to promote awareness amongst exposed dwellers.
3. Knowledge on the principal hazardous volcanic phenomena (ashfall, PDC and lahar) is contrasted (ESD Fig. 6, g6). As many as 75% know what ash is, based on in situ experience,

but at least 36% of the villagers do not know how deadly PDCs can be. The complex processes and effects of PDCs are poorly understood amongst villagers, except school teachers and a few households in Summersari along the K. Koboan valley affected in 1994 and 1995 (Fig. 3). In strong contrast, c. 85.50% of people know lahars and a large majority are able to distinguish hot or cold lahars and banjirs (Indonesian term for hyperconcentrated flow), and how they can be triggered.

4. Widespread knowledge on lahars is corroborated by the fact that almost 50% of people know, at least approximately, lahar occurrence and frequency (ESD Fig. 6, g7). Knowledge on lahars stems from direct or indirect experience, as almost 53% of the villagers know, or have heard of, other persons affected by lahars (g9). However, 42% of the respondents cannot estimate the arrival time of a lahar near their village, hence how much time they would have to escape from the most frequent threat once early warning had been emitted (g8).

5. Knowledge on Semeru's eruptive activity is equally fair as 71% of the respondents estimate that an eruption can last hours to days (ESD Fig. 6, g10). As many as 43.5% answer that lahars can be produced within hours after an eruption, while almost 37% correctly declare that these events can happen without an eruption and result from intense rainfall (g11).

## Survey C+D2

The following nine topics, based on concepts of social science (e.g., Johnston et al., 1999; Paton, 2003; Davis et al., 2005; Haynes et al., 2008a), aimed to define risk perception, awareness and preparedness, as shown in Table 5 and ESD Figures 7A, B. These concepts provide key issues to appraise to which extent population may weigh in volcano risk against daily risks around Semeru.

1. Hazard salience, i.e., the tendency to mention hazards as a problem relative to other concerns and the amount of time spent thinking about the volcanic threat (Davis et al., 2005), does not prevail here. The active volcano is a concern shared by more than 49% of the respondents, but daily hardships are more widespread and pervasive concerns: 68% quote personal or family life, children care and health, and 55% cite limited access to resources and low-income issues (ESD Fig. 7A, g1-3). Questions asked about the Semeru's dangerous activity raised ambiguous answers: the volcano, a protecting feature in dwellers' home backyard, does not seem to be a major concern, although 32% feel worried by potential impacts of eruptions and an equal proportion by lahars.

2. Adaptation to risk relies on the sense of community and social capital, which plays a role on behaviour in case of volcanic crisis (ESD Fig. 7A, g4-6). Villagers participate in solidarity jobs almost daily for the benefit of the group: not only 91% in *kerja bakti* (community service) or *gotong royong* (cooperation in daily life and work, and mutual help in case of disaster), but also in other cultural, religious or sport organization. However, some keep-to-self traits were recognized amongst 47% of respondents, while 13% only are leaders of associations.

3. Most people do not perceive well the likelihood and severity of lahars and PDCs (ESD Fig. 7A, g7-9). Almost 65% and 58% of respondents do not believe that lahars or PDCs, respectively, would hit them again. A reassuring fact, however, is that more than 26% of the respondents are aware that PDCs and lahars might hit them in the future. Over 86% of the population declare having seen a lahar, but less than 50% of them have watched PDCs, mostly through videos, which would explain why villagers believe that PDCs are less likely to occur (and actually they are). Only 22% of villagers have been affected by lahars (g8), perhaps explaining why the perception of lahar likelihood and severity remains relatively low.

4. Where from do villagers perceive lahars and PDCs as dangerous events? Almost 89% of respondents feel that they acquired experience with volcanic threats, directly for almost 46%, vicariously for 23% or indirectly for  $\geq 20\%$  of them. Indirect experience explains why almost 68% of people perceive lahar hazards from events reported by family members or friends (ESD Fig. 7A, g10-12). Because at least 72% of respondents have heard of motorbike accidents across rivers, we may attribute fear related to lahar injuries to vicarious experience (g13, 14). In contrast, people do not “rely” on indirect experience on PDCs as only 14% of them know someone affected by them. A large majority of respondents believe that their estimate on lahar and PDC hazardous effects has been acquired from, firstly experience for 54%, secondly school and authorities for 22%, and thirdly from families and neighbours (g15-17). Flowing lahars appeal more than PDCs: about 55% of respondents declare some interest in lahars, but as little as 15% in PDCs, because the latter are mostly feared with good reason (ESD Fig. 7A, g18, 19).

5. What is the role of past behaviour, memory and self-confidence on the decision to evacuate? Among one third of the villagers who have been evacuated at least once, 28% did not check their decision with anyone, but as much as 43% searched for advice and, a noteworthy c. 12% did not know what to do (ESD Fig. 7B, g20-22). Results demonstrate that the villagers are confused in case of lahars, whatever widespread knowledge and experience



may be. A reassuring fact is that 41% of the population feel that negative lahar-related memories and fear can compel them to evacuate.

6. Villagers' empowerment, i.e., feelings regarding ability to protect oneself and/or their family in the event of an eruption (Davis et al., 2005), is low, as almost 54% correctly think that the flows are too powerful to be overcome, but 36% of them admit that overcoming the impacts of the flows is also difficult or impossible (ESD Fig. 7B, g23-25). However, 42% of the villagers claim that they could do something about flow impacts, such as prevention and evacuation solutions, while a mere 7.5% quote protection works. When facing an eruption or a crisis, villagers' self-efficacy reaches low level, with more than 43% and 18% of them feel little to entirely self-confident, respectively (g26).

7. Trust in official early warning messages and accurate information about imminent eruptions are two major issues for evacuation policy (Haynes et al., 2008b). Almost two thirds (65%) of villagers declare that they will abide by the evacuation order, but 7.5% affirm that they will never obey, and as much as 12% do not trust anyone (ESD Fig. 7B, g27-31). As many as 86% of people indicate that they trust in at least one or all of the warning messages, with the authorities, i.e., BNPB staff, being the most trusted source. An increasing number expects warning messages from modern devices (smartphone, TV, and radio). Trust in government agencies is based on personal experience during past evacuations and widespread respect for the authorities in Indonesia. Despite obedience and respect, a majority of the population needs to check before acting: 53% of them declare they will first check the warning messages with their neighbours before evacuating (g30). There is room for improving information about mitigation policy and risk communication, as a non-negligible part of the villagers do not trust anyone (12%), do not answer (14%) or misunderstand the question (5%).

8. Overall, people appreciate government actions that promote preparedness for natural disaster, although such appreciation is a sensitive subject and many answers may therefore be biased. The positive appreciation steadily increases from 41-48% at nation and region scale to 58% at local scale (ESD Fig. 7B, g32). However, a large number of the population (21 to 39%) does not answer, perhaps on fear of denunciation or political reason, or does not understand the question. Up to 20% of the respondents declare that the governance could be improved in terms of mitigation nationwide and regionally, but they seem less skeptical about the local administration. This suggests that the lack of appreciation of the actions for preparedness may be due to poorly known crisis management examples in Indonesia's remote

areas, such as the poorly managed tsunami disaster in Palu, Sulawesi (2018), quoted by several respondents.

9. Ranking personal feelings about volcano, lahar and PDC hazards is akin to affective responses (Wei and Lindell, 2017). Villagers living on Semeru slopes are not afraid of the eruptive activity or lahars, probably due to a long, shared experience: at least 44% of them argue that they feel “calm”, men optimistically declaring such feeling more than women. A limited <20% of people boast about being calm in case of PDC events, but more than 52% of the respondents are afraid and over 19% concerned about PDCs, as many of them watched videos of their deadly effects on Merapi in 2010. A correlation exists between “afraid” or “concerned” feelings and knowledge of volcanic phenomena (ESD Fig. 7B, g33): frequent lahars are well known amongst villagers, who watch them every rainy season from safe distance along active rivers. In contrast, PDCs are poorly understood, un-frequently observed, and their effects are perceived as deadly and destructive from videos and TV reports.

### **Survey D1: Belongings, livelihood, evacuation facilities and handicap**

1. The first asset concerns home, land and belongings. Almost 90% of the respondents own their homes, either 58% of them inherited it from their parents with whom they live under the same roof, or 32% of them inherited the land on which they built their house (ESD Fig. 8A, g1-3). House rental is uncommon (10%), but many more villagers rent a rather small farmland around. Small land agricultural economy prevails, as most properties are smaller than one acre (0.4 ha), and land value is low (8-15 US\$/m<sup>2</sup> per acre). Almost 78% of the villagers own a small garden, but a minority of them possess a sizeable piece (1 ha) of land, rice field or plantation, the property being smaller (0.2-0.5 ha) for trees and fruits (g3). Half of the respondents cultivate and harvest one particular crop (rice, manioc, coffee, fruit trees), but another half of farmers tend at least two crops (ESD Fig. 8A, g4). Despite the lack of available space outside cultivated land, almost 51% of households hold some storage facility (ESD Fig. 8A, g5). Widespread trade in Javanese rural communities includes a dense network of shops in *dusun* and markets in *Desa* (ESD Fig. 8A, g6). Trade or exchanges between agriculture products are intensive inside (almost 48% of the respondents) and outside villages (>15%), or both (c. 27%). Hence, a small amount (c. 8%) of households appears to be landlocked and self-sufficient.

Household tangible assets are twofold (ESD Fig. 8A, g7). 1) Home belongings are contrasted: an overwhelming majority of people (c. 90%) own at least one motorbike and one TV, but

much less electronic appliances. On the contrary, cars are scarce (<15%) in villages and restricted to the factory entrepreneurs and government officials in towns. 2) Animals represent a pivotal asset in rural Javanese communities. A large majority owns farm animals: >67% people have poultry, c. 42% feed sheep, but <10% only raise big cattle for they need more space, fodder and care.

2. The household livelihood, second asset, determines the measure of available resources. Livelihood consists of informal activities for 55%, small businesses for 33%, while public jobs occupy a mere 11% (ESD Fig. 8A, g8). About 74% of households receive earning from one or two family members, while 25% middle- to high-income homes host 3 to 5 contributory persons from two families (g9). Significantly, about 8% of family members (mostly young adults and women) work or have worked for a few years outside Indonesia (esp. Malaysia), and another 7.50% in large cities of Java or in Bali, as part of temporary migration, which provide fresh money to households. A number (22%) of households suffer from very low income (under the poverty line), twice as much as the Indonesia average 9.8% (2017). Total income represents less than the nationwide monthly salary threshold (1,961,000 IDR= 121 US\$ as of 2019) for 59% to 64% of the households (g10), but at least 40% of respondents declare earnings above this threshold.

Financial issues represent a sensitive subject, so biases may largely impair replies to questions related to household income, insurance and loans. Nevertheless, 46% admit that they are indebted to banks and over 33% resort to microloans, but an overwhelmingly 73% is not insured against any kind of loss (ESD Fig. 8B, g11-13). In this context, the resulting answer: “almost three quarters of families cannot rebuild their house in case of a natural disaster or fire due to limited resources and lack of insurance” does not come as a surprise (g14). Furthermore, no retrofitting building policy has ever been implemented in *dusuns* exposed to volcanic flows.

3. The third asset considers evacuation experience and facilities in case of volcanic crisis. Firstly, over 73% of respondents declare that access to evacuation facilities (road network, signs and shelters) is good to very good, but 61% of people consider themselves without protection works against the effects of volcanic flows, despite existing dykes and check dams across the active rivers (ESD Fig. 8B, g15, 16). Secondly, more than one quarter of the surveyed villagers were evacuated at least once in 2002-2003, and older persons in 1994-95 or 1981 due to large eruptions and voluminous lahars (see ESD Fig. 7B-21). However, only 3% of the respondents (the eldest persons), experienced evacuation three times during their

lifetime, a data to inscribe in the context of Semeru's persistent activity. One of the reasons is that eruptive activity remained mild (VEI2) most of the time since 1967, with intermittent VEI3 pulses every 25 years on average over the past 137 years (Thouret et al., 2007). Thirdly, and more worrying, 41% of the respondents suffer at least one handicap, either physical, economical or psychological, which may prevent them from accessing shelters in case of evacuations (ESD Fig. 8B, g17).





	TR167	habitat	3A	B	113,029496	-8,117355	698		TU6	worker, sand v	2		x	
	TR 168	hab+shop	3B	B	113,029685	-8,116814	694.15	RT1RW9	TU6	farmer, shop	2		x	
	TR169	habitat	3B	B	113,028386	-8,116222	706	RT2RW9	TU6	farmer	2		x	
	TR170	hab+shop	4	C	113,028765	-8,116354	705.85	RT2RW9	TU7	lector, sells fr	3		x	
Candipuro	CDP 171	antor, traditio	3B	B	113,077299	-8,190671	329.10		not drawn		3	x		
Candipuro	CDP 172	Puskesmas	4	C	113,077402	-8,190900	326.85		not drawn	nkesdes in Ki	5	x		
Sumberwuluh	SBW 173	antor, traditio	3B	B	113,044714	-8,184782	449.40		not drawn		4			
Jabon	JB 174	Puskesmas	5	C	113,059000	-8,118915	552.40		not drawn	Puskesmas	4	x		
Tulungrejo	TR 175	hab+shop	2B	A	113,024559	-8,116117	725.40	RT6RW9	TU6	shop	3		x	
D= Pasrujambe	TR 176	hab+business	3A	B	113,024616	-8,115945	725.60		TU6	ar, garage, cer	3		x	
K= Pasrujambe	TR 177	hab+shop	3B	B	113,023718	-8,115366	732.30		TU6	usiness, shop,	1		x	
	TR 178	habitat	3A	B	113,023235	-8,114204	749.55		TU5	farmer	3		x	
	TR 179	habitat	3A	B	113,023118	-8,113984	751.30		TU5	neer in agricu	3		x	
	TR 180	habitat	3A	B	113,023314	-8,113945	752.30		TU5	ewife, farm w	1		x	
Jabon	JB 181	habitat	3B	B	113,023990	-8,111545	776.75		TU3	e, sand work	2	x		
	JB 182	habitat	3A	B	113,024111	-8,111684	774.10		TU3	farm worker	2	x		
	JB 183	hab+big shop	3B	B	113,025504	-8,113157	761.75		TU3	armer, big she	3	x		
	JB 184	habitat	3A	B	113,025681	-8,113217	761.65		TU3	ent, worker m	2	x		
Tawonsongo	TWS 185	Ponkesdes	3B	B	113,022788	-8,109634	801.95			nurse	3		x	
Juranglangak	SE RE 186	Puskesmas	5	C	113,097966	-8,101338	426.05		JRL7	ar Kantor De	2	x		
Juranglangak	SE RE 187	habitat	2B	A	113,097420	-8,101315	431		JRL7	il business, ret	3	x		
D= Senduro	SE RE 188	habitat	3B	B	113,096861	-8,101183	436.80		JRL7	farm worker	3	x		
K= Senduro	SE RE 189	antor, traditio	4	C	113,097020	-8,100967	434		JRL7		3	x		
	SE RE 190	School TK	3B	B	113,097354	-8,101349	432.05		JRL7	her, kinderga	2	x		
Sumbermulyo	SUMB 191	habitat	3A	B	113,091774	-8,101477	449.50		SM8.4	farmer, retaile	3	x		
& Juranglangak	SUMB 192	habitat	3B	B	113,091877	-8,101418	449.30		SM8.4	ch & rescue t	3	x		
D= Senduro	SUMB 193	habitat	3B	B	113,092272	-8,101187	450.45		SM8.4	wife, market r	2	x		
K= Senduro	SUMB 194	habitat	3B	B	113,091988	-8,101185	455.30	RT2RW14	SM8.4	ver, HIFI reta	3	x		
	SUMB 195	habitat	3A	B	113,092002	-8,100989	454.10		SM8.4	ylor, tree grow	3	x		
	SUMB 196	habitat	3B	B	113,091591	-8,103886	423.60	RT4RW14	SM9	diploma Unive	3	x		
	SUMB 197	habitat	4	C	113,092304	-8,103494	433.10		well off	SM9	keeper, farm	2	x	
	SUMB 198	hab+shop	3B	B	113,091636	-8,102428	443.50	RT4RW14	SM9	ife, shop (gas	3	x		
	SUMB 199	habitat	3A	B	113,091312	-8,102539	440.20		SM9	usiness, mark	4	x		
	SUMB 200	habitat	3A	B	113,091283	-8,102354	441.35		SM9	retired	3	x		
	SUMB 201	habitat	3B	B	113,091403	-8,102403	439.65		SM9	of school rest	2	x		
Juranglangak	SE JUR 202	habitat	3B	B	113,102484	-8,103573	387.70	RT1RW19	RE3	ctor, market r	2	x		
Rekesan	SE JUR 203	hab+shop	3A	B	113,101505	-8,103586	397.90		RE3	taurant, mark	3	x		
D= Senduro	SE JUR 204	habitat	3A	B	113,100560	-8,103554	403.75		RE3	retired, farm	3	x		
K= Senduro	SE JUR 205	habitat	3B	B	113,100510	-8,103180	403.65		RE3	usewife, retai	2	x		
	SE JUR 206	habitat	3B	B	113,100260	-8,103099	406.35		RE3	retired	2	x		
	SE RE 207	habitat	3A	B	113,099515	-8,102781	408.45	RT1RW17	RE3	usewife, farm	2	x		
Juranglangak	SE RE 208	habitat	3A	B	113,098487	-8,102306	416.30		RE8	wife, wood fa	2	x		
Rekesan	SE RE 209	hab+shop	3A	B	113,096912	-8,103089	424.95		RE3	ss, birds & sc	3	x		
	SE RE 210	habitat	3B	B	113,096778	-8,103055	426.65		RE3	ife, works in h	2	x		
	SE RE 211	habitat	3A	B	113,099404	-8,104628	397.35		RE3	struction wor	3	x		
	SE RE 212	habitat	3A	B	113,099230	-8,104931	401.20	RT6RW18	RE3	farmer, elder	3	x		
	SE RE 213	hab+shop	3A	B	113,099330	-8,104831	402.25	RT6RW18	RE3	small restuar	3	x		

**USE categories: (5)**

**Kantor= Administration, office**

**School= Education + includes Observatory, shelter, sport facilities**

**Habitat = Residential (home)**

**Hab+shop= Residential AND business** Include hotel, B&B in business

**Puskesmas (small hospital), Pokesdes (dispensary)= Health centres**

**Lines an rows in blue are urban habitat in small towns**

Date		Village (Desa): SupitUrang				District:		Kecamatan Pronojiwo / Kabupaten Lumajang														Comments			
Team		IPB-UGM - UCA				Neighbourhood		RT / RW																	
N°	N° Block	N° Building	Use	Floor number	Main Typology	Roof				% Openings				General Opening	Opening Type			Position with respect to the river				Maintenance			
						Light material	Metal sheet	Tiles	Pitched RC	<10	10-30	30-50	>50		%	Resistant	Regular	Weak	Angular	Parallel	Perpendicular	NA	Good	Regular	Poor
5	15	08	habitat	1	B-	X Timber			X			X		-40			X		X	X			X		Low-quality house
7	16	06	habitat	1.5	C	X Timber	X		X			X		40		X	X						X		Regular C+
11	15	06	habitat	1	A	X Timber	X		X			X		25			X		X	X			X		Wood, simple, poor quality
17	15	06	habitat	1.5	D+	X with masonry	X with timber		X			X		30			X		X	X			X		Several dependences, good quality D+

EDS Table 2. Example of survey file for assessing the structural typology of buildings.



House type	Size on average	Number of stores, foundation	Construction material	Roof and timber, ceiling	Roof type and cover	Ground, windows	Front and porch	Maintenance
1A, 1B	Small < 30 m <sup>2</sup>	One No foundation	Bamboo, vegetal material	Zinc, Light wood No ceiling	Pitched zinc	Bare; No windows	Bare ground	Poor Shanty aspect
2A, B	Small < 40 m <sup>2</sup>	one	Plywood Simple stone foundation	Light wood No ceiling	Pitched Wood or zinc	Cement Small wood windows	Bare front side	Poor to regular
3A	modest 40 – 70 m <sup>2</sup>	one	Simple masonry Stone foundation	Wood, ceiling	Pitched Zinc	Cement Small windows	Cement front side, thin columns	Regular
3B	Average 50-70 m <sup>2</sup>	1.5	Brick, mixed Masonry foundation	Large, strong wood; Wood ceiling	Pitched Zinc or tiles	Ceramic, large windows	Ceramic front side, concrete columns	Fair to well, painted
4	Large >80 m <sup>2</sup>	1.5 or 2	Brick	Large, strong wood; RC ceiling	Pitched, large, 4 sides, tiles	Large, glass and steel windows	Decorated, ceramic, concrete columns	Good to excellent
5, in towns	> 120 m <sup>2</sup>	2 to 3 Master construction design	Reinforced concrete RC slabs, balcony	Metal timber Concrete ceiling	Pitched, large, 4 sides, tiles	Large, glass, steel windows	Large front, Decorated, ceramic, shop	Good to excellent

ESD Table 3. Structural types of the building stock

Cluster 1	Cluster 2	Cluster 3	Cluster 4
Categories with high frequency			
D2.Q3. Individualist behaviour (keep to self)? No B.Q13. How long can lahar occur after a volcanic eruption from Semeru? Can happen without eruption D1.Q19. Is there any civil protection work against volcanic phenomena? No C.Q8. Do you feel that a lahar can hit again? More than once C.Q9. Do you feel that a PDC can hit again? More than once D1.Q20. Do you or does your family suffer from any personal, physical handicap economic hardship? No C.Q30. Do you feel self-confident in case of an eruption? Very confident B.Q2. Do you know what year this volcano last erupted? Knows approximately	D2.Q3. Individualist behaviour (keep to self)? Yes D1.Q20. Do you or does your family suffer from any personal, physical handicap economic hardship? Yes B.Q9. Lahar occurrence estimate: Precisely C.Q30. Do you feel self-confident in case of an eruption? Afraid B.Q2. Do you know what year this volcano last erupted? Knows B.Q2. Do you know what year this volcano last erupted? Knows D1.Q19. Is there any civil protection work against volcanic phenomena? Yes A. Q5. Household: Number of families? 1 C.Q17. How did you behave that day? Evacuated or auto-evacuated D2.Q12. How do you feel about the eruption? Quiet C.Q29 Solution choice to overcome flow effects: Prevention and evacuation	C.Q15. Can you identify or discuss a particular lahar that you remember? No C.Q19. Can you describe a lahar? Can't B.Q13. How long can lahar occur after a volcanic eruption from Semeru? Doesn't know C.Q25. Do you like to observe a lahar/HCF from a safe distance? Nothing C.Q12. Effect of stories about lahar: Never C.Q5. Have you ever seen a lahar? No B.Q7. Do you know what PDC is? Doesn't know Distance to river: Far away C.Q6. Have you ever seen a PDC? No	C.Q16. How long ago did this lahar occur? Weeks/months C.Q18. Do you feel that this memory can influence how to behave (e.g., running away or being evacuated)? Never or doesn't B.Q13. How long can lahar occur after a volcanic eruption from Semeru? Just after an eruption C.Q28. Do you feel that such a phenomenon is so powerful than mankind cannot do anything about it? Yes but something can be made about the phenomenon B.Q10. Can you estimate the arrival time of a lahar to your village once it has been triggered on the mountain? 10 to 30 minutes B.Q5. Does he/she know the hazard-zone colour meaning? Knows the colours and meaning D2.Q2. Do you participate in <i>kerja.bakti</i> ? No C.Q17. How did you behave that day? Remained there but searched for order/advice D2.Q11. Do you check upon warning? Trust, no need to check
Categories with low frequency			
D2.Q3. Individualist behavior (keep to self)? Yes B.Q2. Do you know what year this volcano last erupted? Knows C.Q8. Do you feel that a lahar can hit again? Never or doesn't know D1.Q19. Is there any civil protection work against volcanic phenomena? Yes D1.Q20. Do you or does your family suffer from any personal, physical handicap economic hardship? Yes C.Q30. Do you feel self-confident in case of an eruption? Afraid B.Q13. How long can lahar occur after a volcanic eruption from Semeru? Just after an eruption	D2.Q3. Individualist behaviour (keep to self)? No D1.Q20. Do you or does your family suffer from any personal, physical handicap economic hardship? No C.Q30. Do you feel self-confident in case of an eruption? Very confident D1.Q19. Is there any civil protection work against volcanic phenomena? No C.Q8. Do you feel that a lahar can hit again? More than once B.Q9. Lahar occurrence approximate estimate C.Q9. Do you feel that a PDC can hit again? More than once	C.Q19. Can you describe a lahar? Yes C.Q15. Can you identify or discuss a particular lahar that you remember? Yes B.Q13. How long can lahar occur after a volcanic eruption from Semeru? Can happen without eruption C.Q18. Do you feel that this memory can influence how to behave (e.g, running away or being evacuated)? Yes C.Q5. Have you ever seen a lahar? Yes C.Q1. In your daily life, do you feel worried or concerned about lahar, volcano or something else? Volcano	D2.Q2. Do you participate in <i>kerja.bakti</i> ? Yes C.Q18. Do you feel that this memory can influence how to behave (e.g, running away or being evacuated)? Yes B.Q13. How long can lahar occur after a volcanic eruption from Semeru? Can happen without eruption C.Q16. How long ago did this lahar occur? 10 years C.Q35. Do you believe messages and/or do you try to check the content? Yes, I trust to check with my neighbours B.Q5. Does he/she know the hazard-zone colour meaning? Doesn't know

ESD Table 4. Four clusters based on category frequency

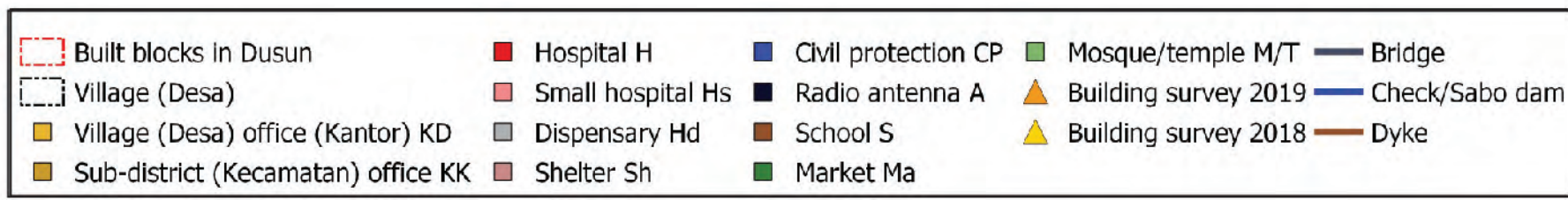
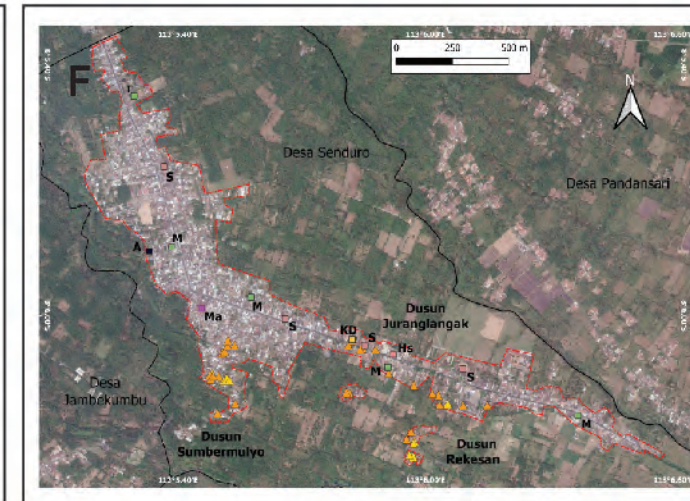
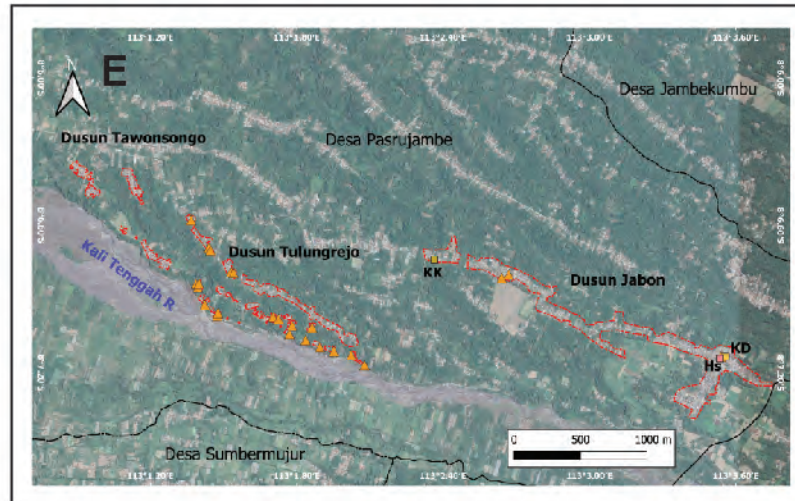
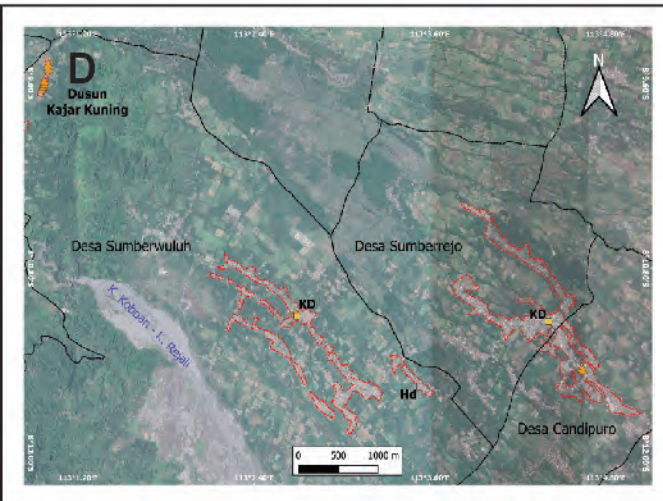
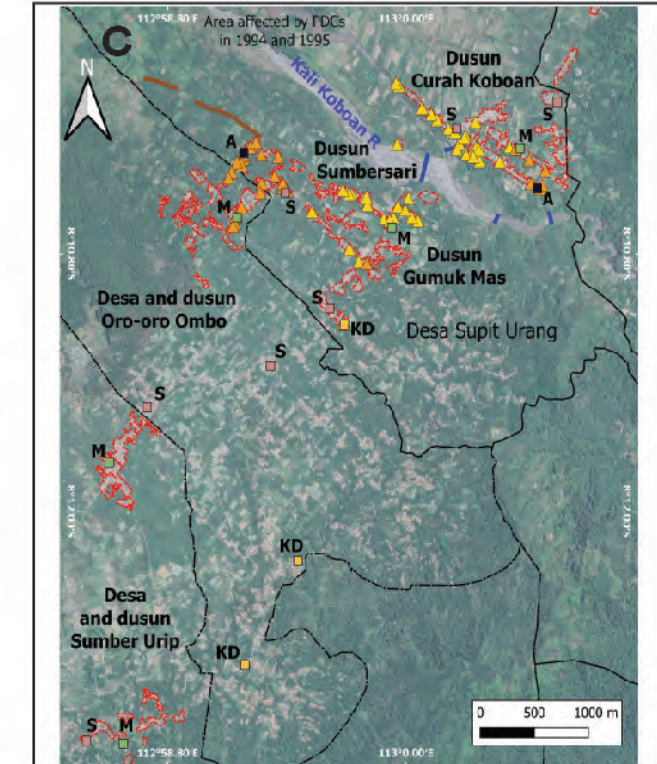
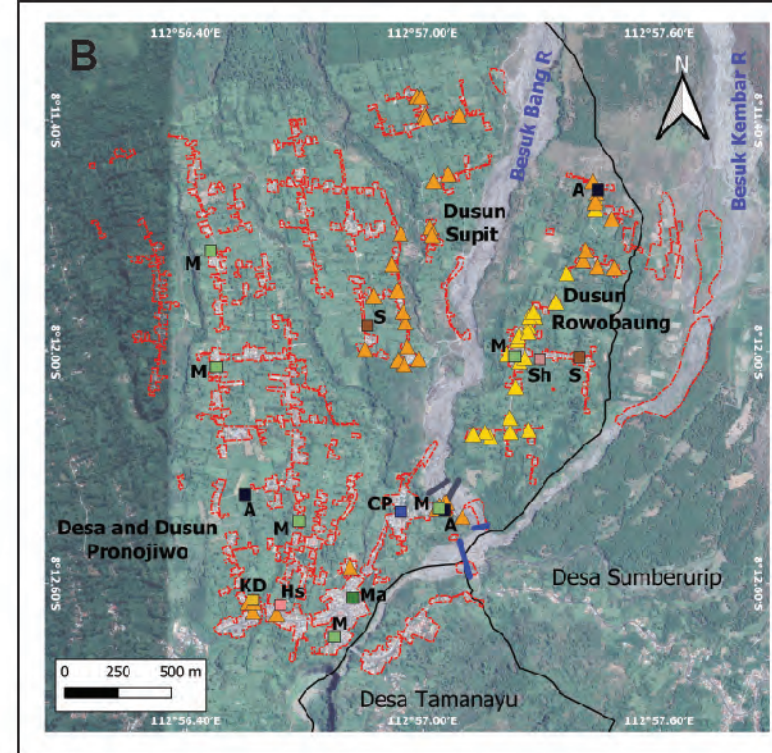
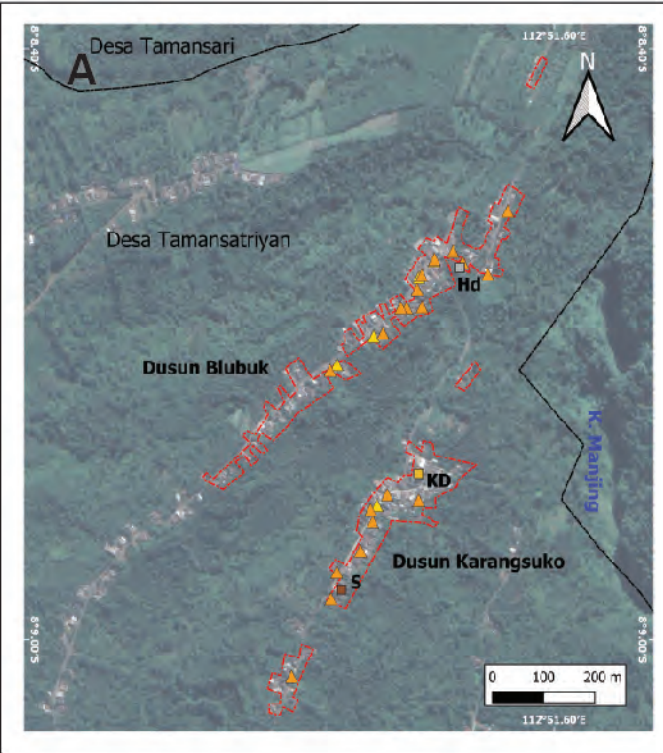
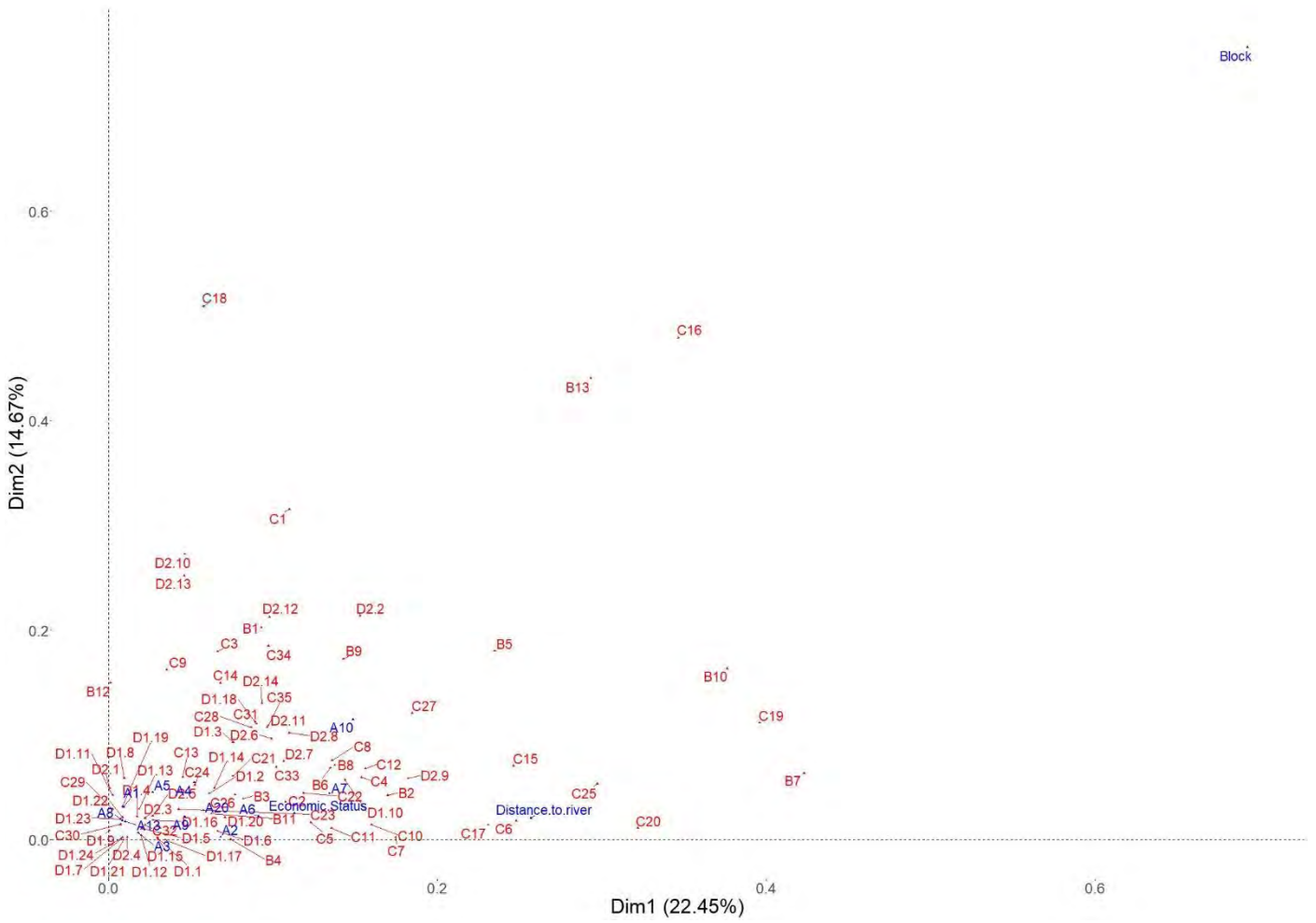
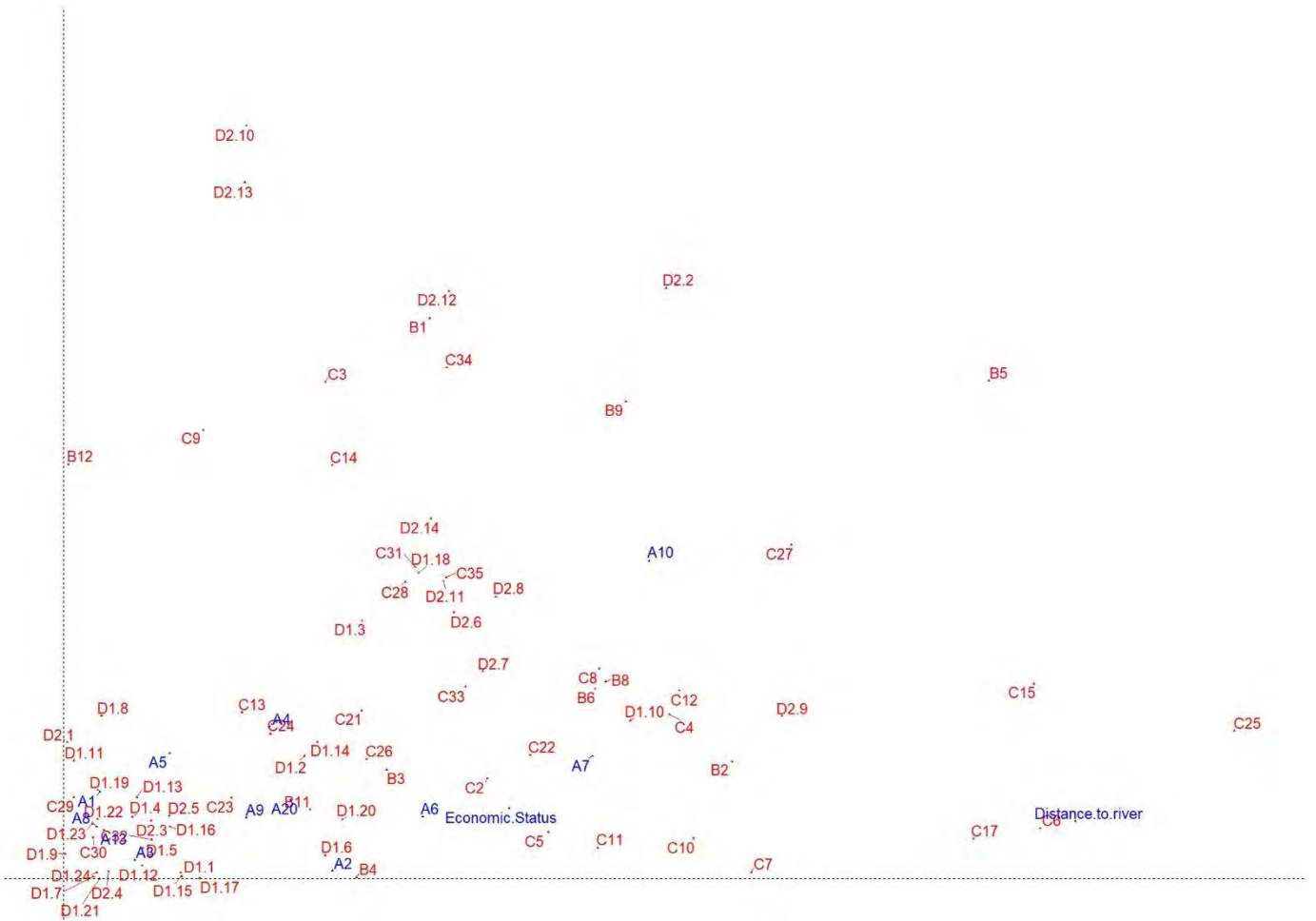


Fig. 1 A-F

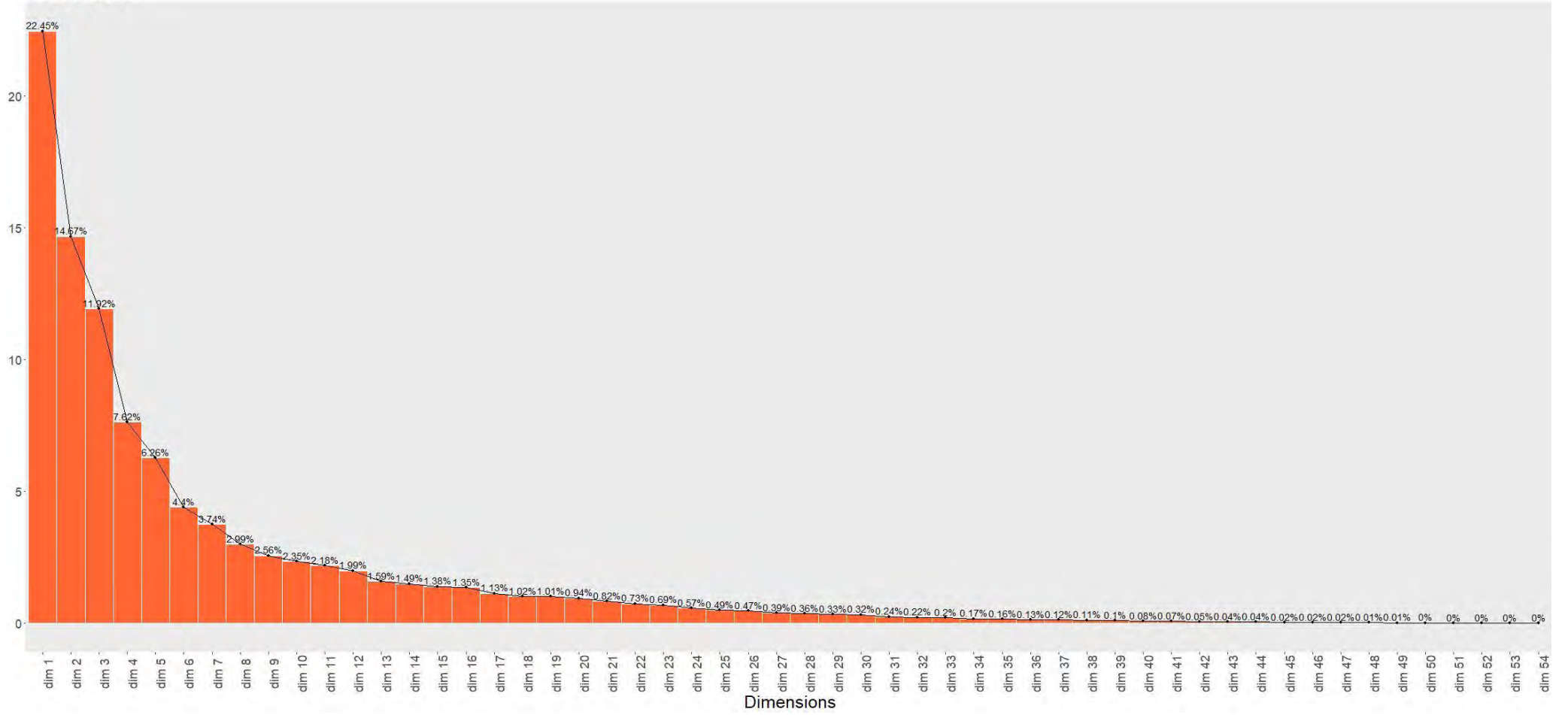


ESD Fig. 2A

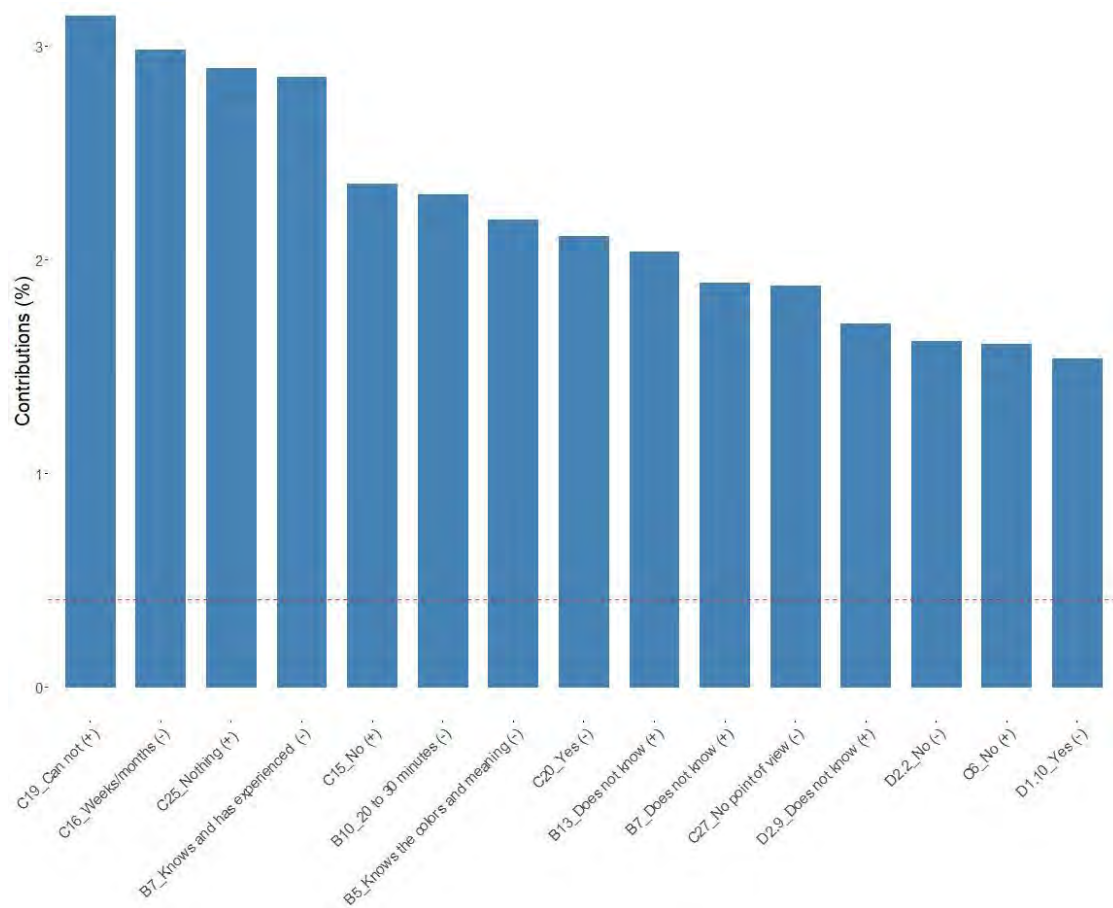


ESD Fig. 2B

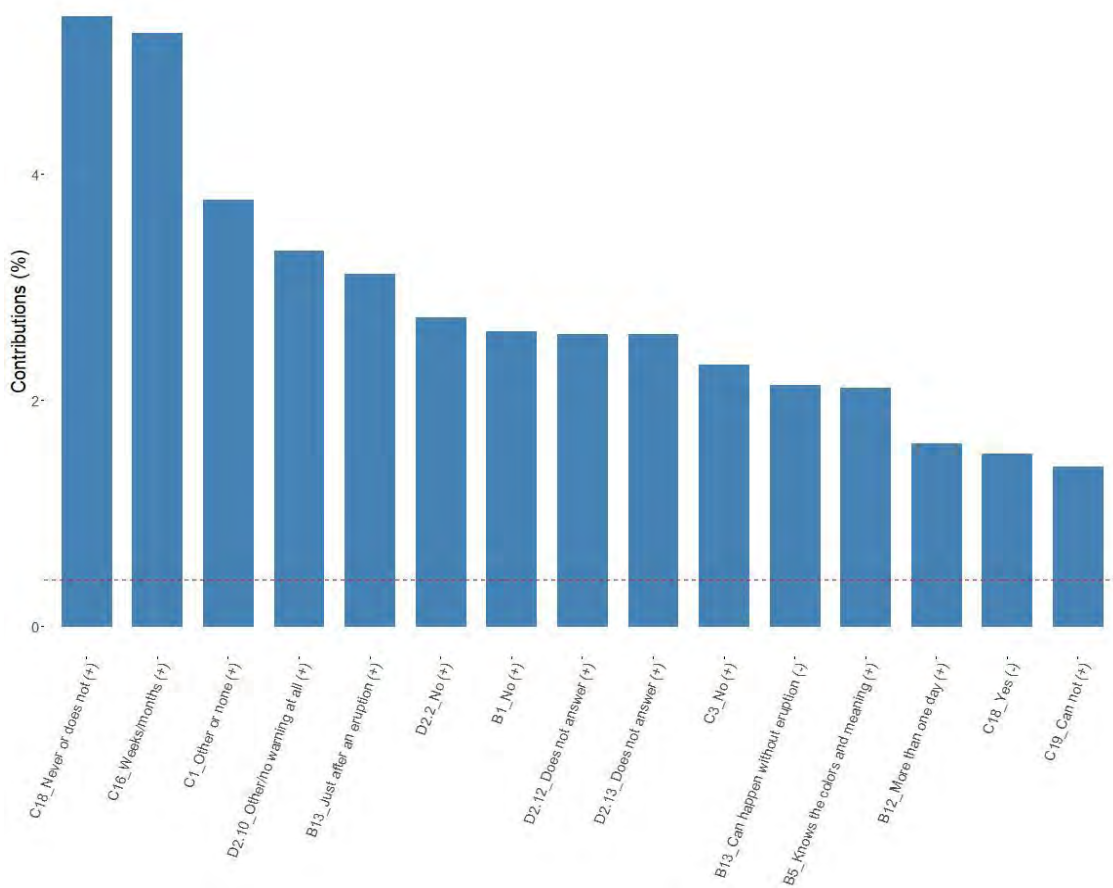
# Scree plot



ESD Fig. 3

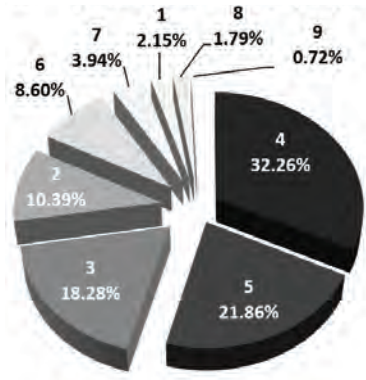


ESD Fig. 4 A



ESD Fig. 4 B

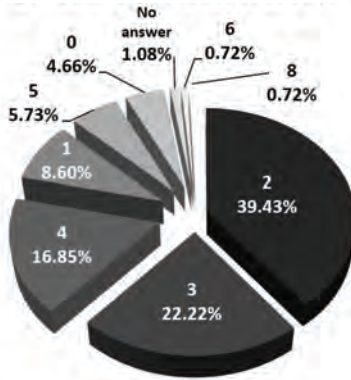
1 Household: Total of people



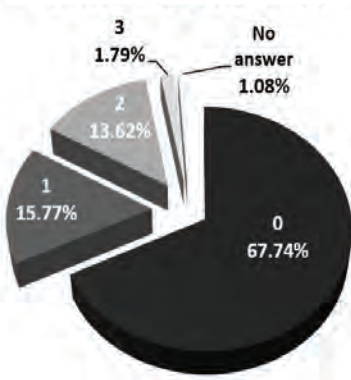
2 Household age group 1: 0-14 yr



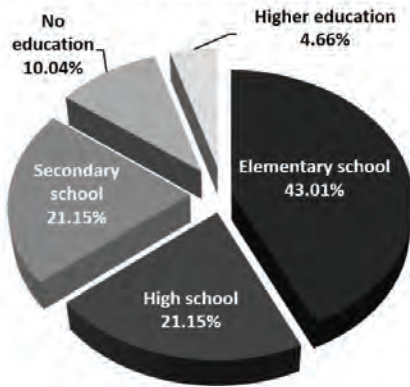
3 Hshd age group 2: 15-60 yr



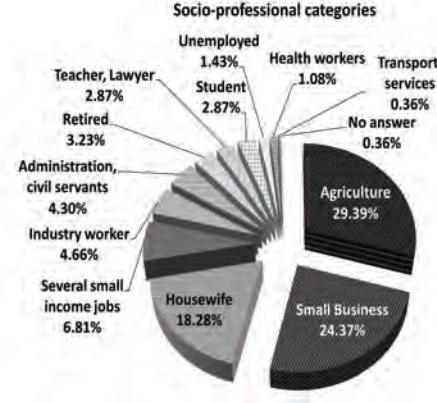
4 Hshd age group 3: > 60 yr



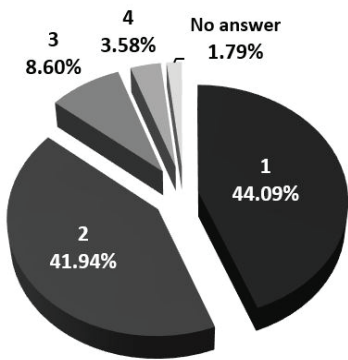
5 Education level



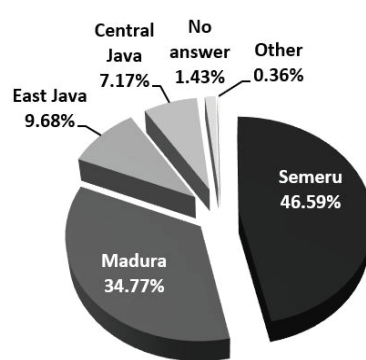
6 Socio-professional categories



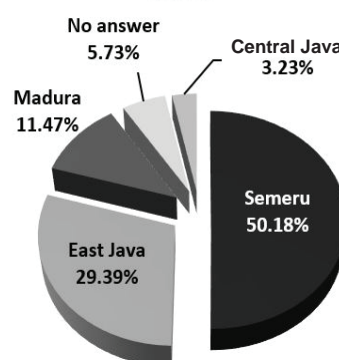
7 Geographical origin of the respondents



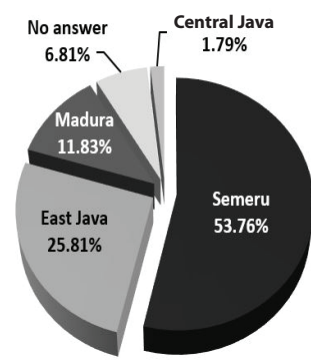
8 Geogr. origin of the father



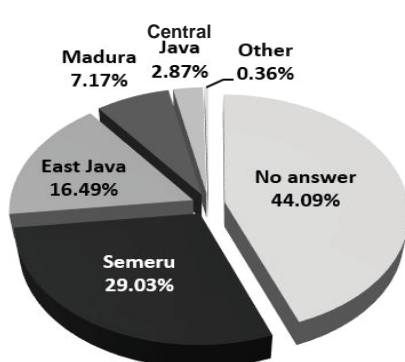
9 Geogr. origin of the mother



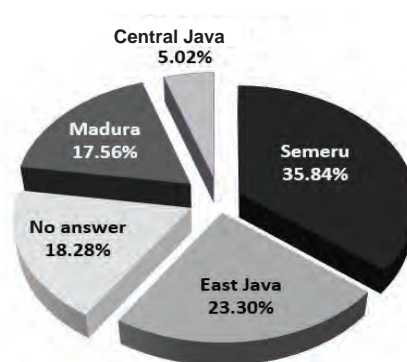
10 Geogr. origin of the grandfather



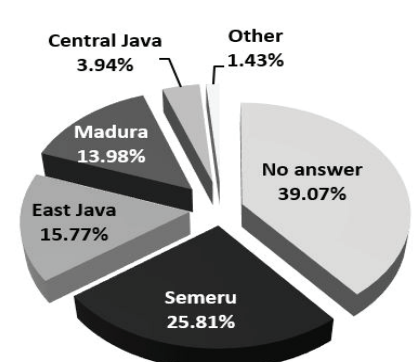
11 Geogr. origin of the grandmother



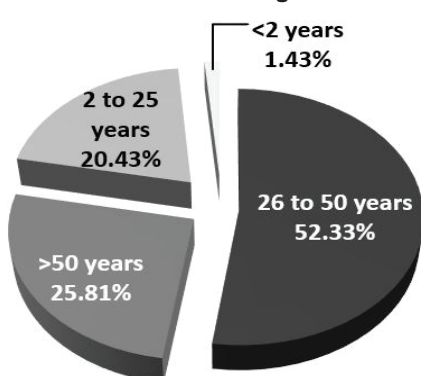
12 Geogr. origin of the great-grandfather



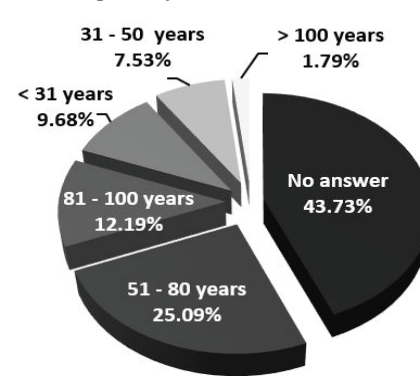
13 Geogr origin of the great-grandmother



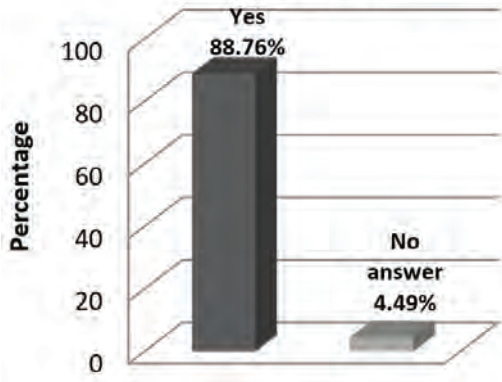
14 Resident's time living in the area



15 Have long have your ancestors lived in the area?



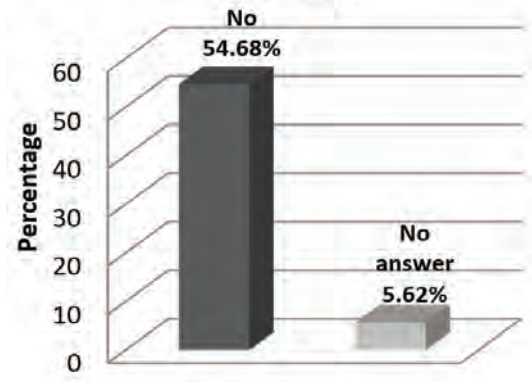
1. Can you name the nearest volcano to your home?



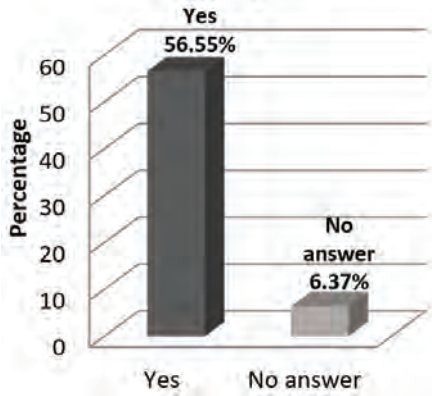
2. Do you know what year this volcano last erupted?



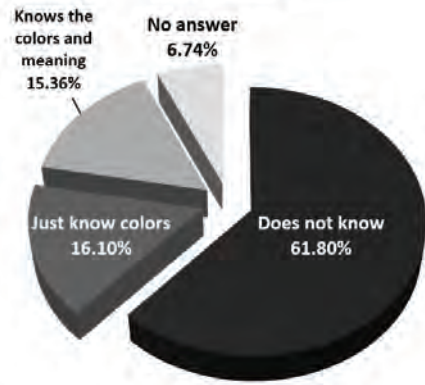
3. Is he/she able to read the hazard-zone map?



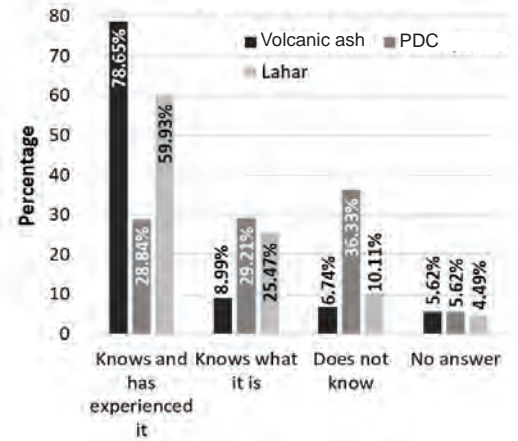
4. Can he/she locate his/her village?



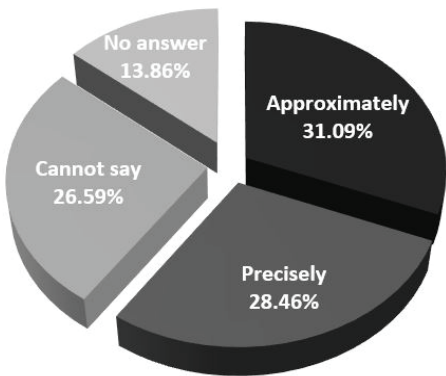
5. Does he/she know the hazard-zone colour meaning?



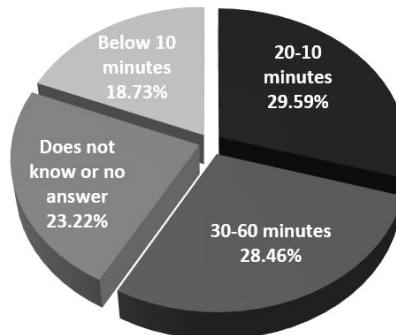
6. Do you know what is:



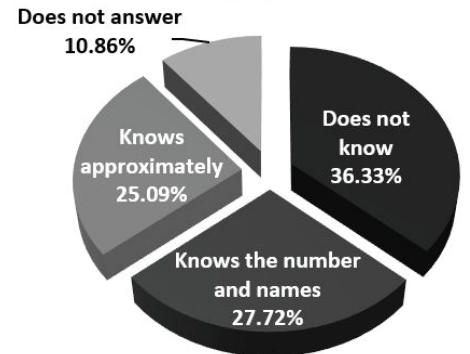
7. Lahar occurrence estimate



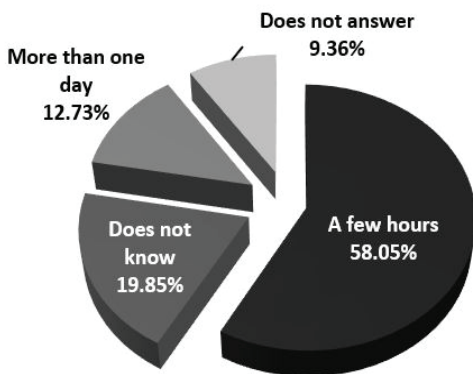
8. Can you estimate the arrival time of a lahar to your village once it has been triggered on the mountain?



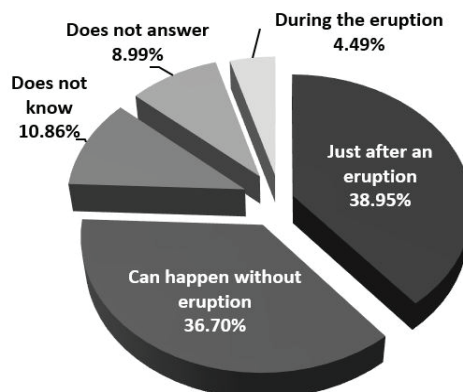
9. Do you know of any victim or/and injured people?



10. How long can a volcanic eruption from Semeru last?



11. How long can lahars occur after a volcanic eruption from Semeru?



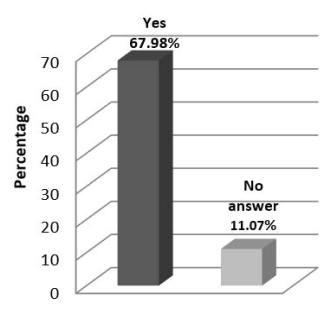
ESD Fig. 6



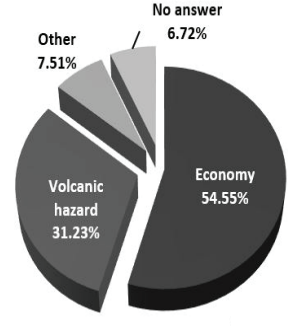
1 In your daily life, do you feel worried or concerned about:



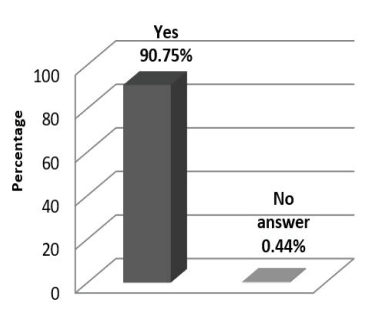
2 Are you concerned about you and/or your family daily life?



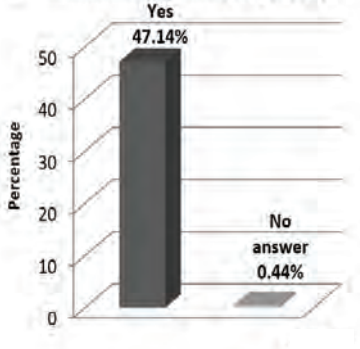
3 If yes, what are you concerned about?



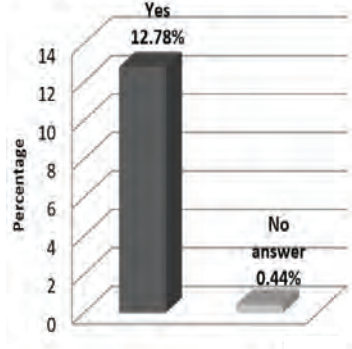
4 Do you participate in solidarity work or community service?



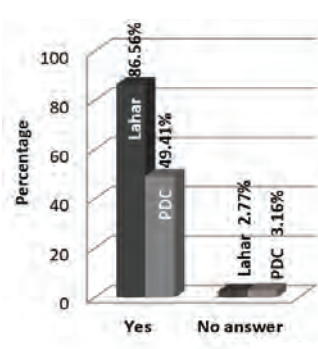
5 Individualist behavior (keep-to-self)



6 Are you a leader of any association?



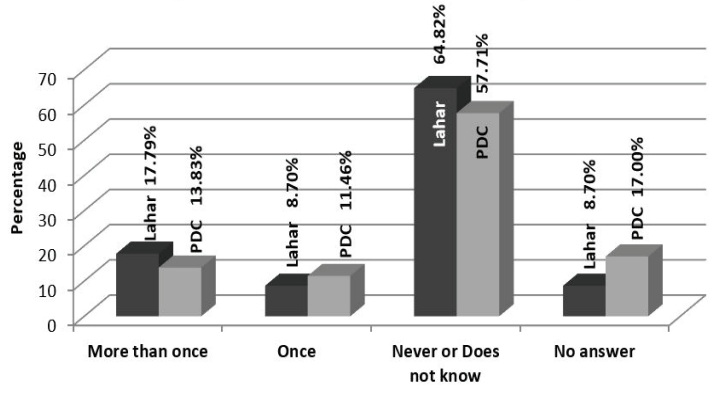
7 Have you ever seen a lahar or a PDC?



8 Have you ever been affected by a lahar (injury, flooded house)?



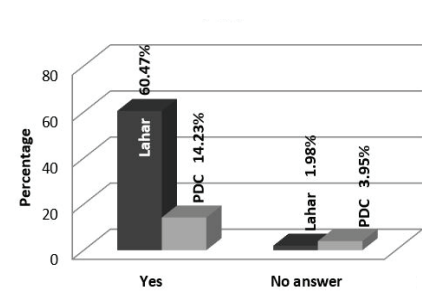
9 Do you feel that a PDC or a lahar would hit you again?



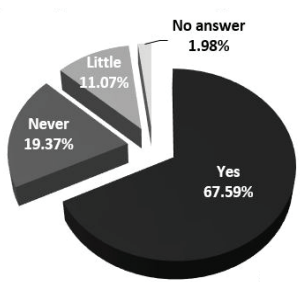
10 What sort of experience allows you to estimate lahar and/or PDC danger?



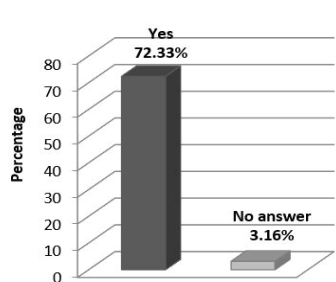
11 Do you know of a family member or a friend who was affected by a lahar/PDC?



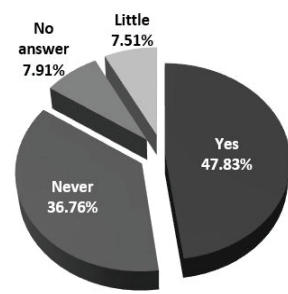
12 Did his/her stories have an effect on how you deem a lahar dangerous?



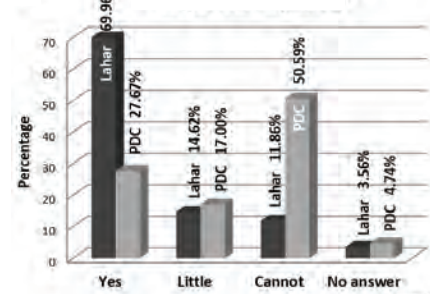
13 Do you know of anyone who had a car or motorbike accident last year?



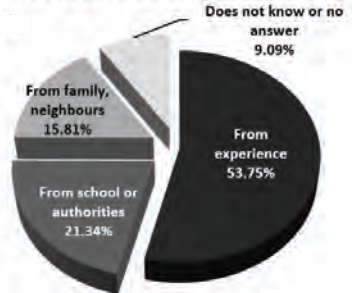
14 Do you feel worried or scared about such accidents, and more than lahars?



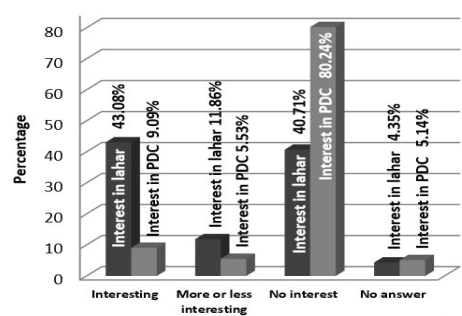
15 Can you describe/draw a:



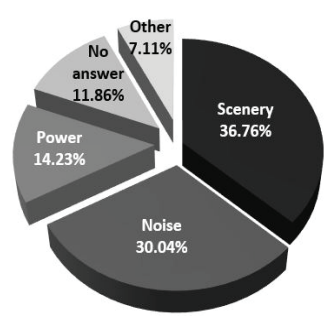
17 How do you know about a lahar, a PDC?



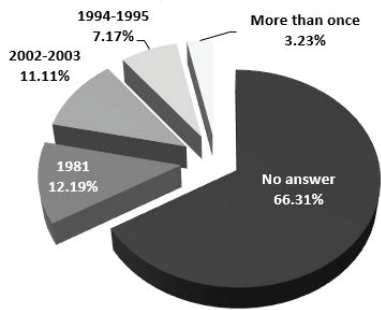
18 Does a lahar or PDC call your attention?



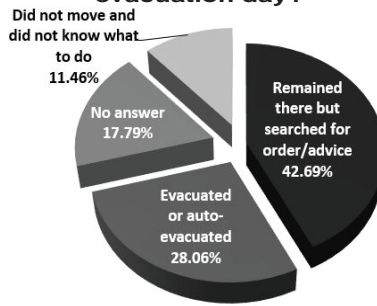
19 What does attract you most?



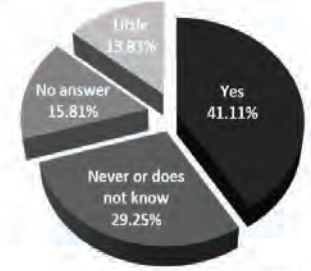
**20 Have you ever been evacuated?**



**21 How did you behave on the evacuation day?**



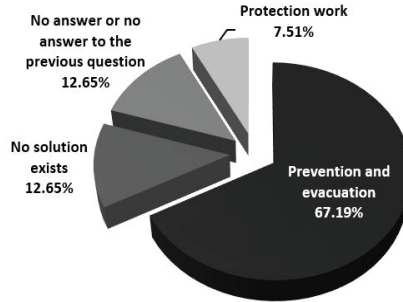
**22 Do you feel that this memory can influence how to behave?**



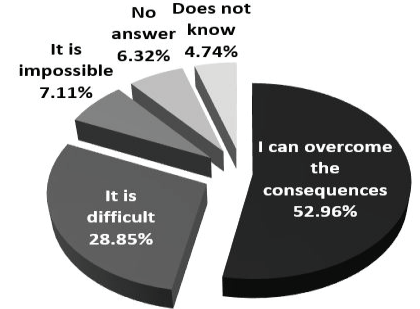
**23 Is this phenomenon so powerful that mankind cannot do anything about it?**



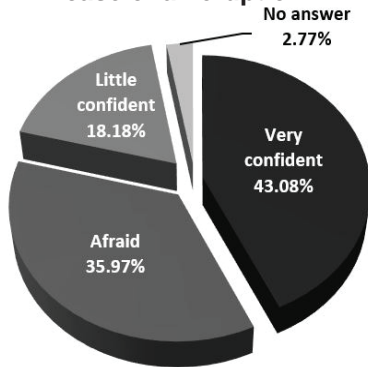
**24 How can the phenomenon or its effects can be overcome?**



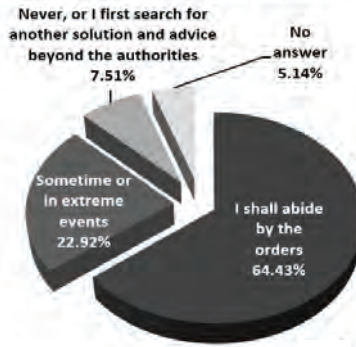
**25 Are you empowered to overcome the consequences?**



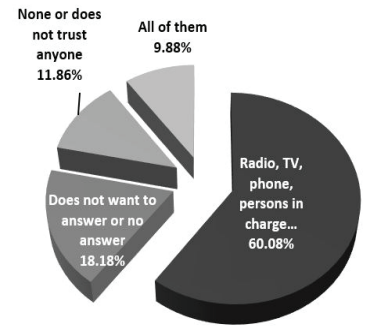
**26 Do you feel self-confident in case of an eruption?**



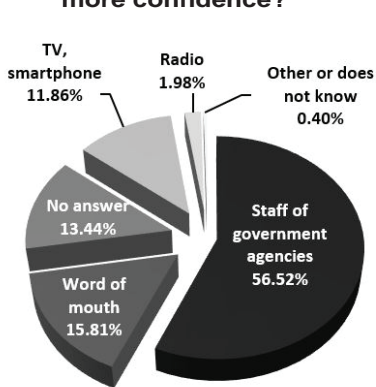
**27 Will you comply with the evacuation order in any type of situation?**



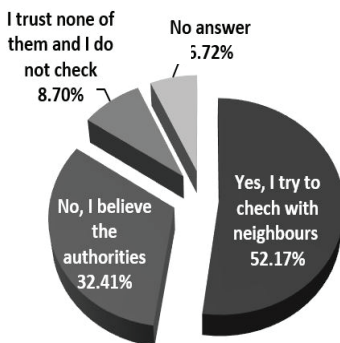
**28 Whom do you receive warning messages from in case of lahar?**



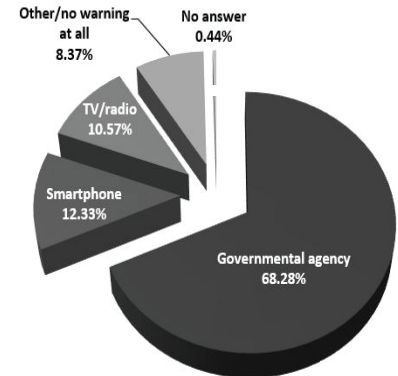
**29 In which one do you have more confidence?**



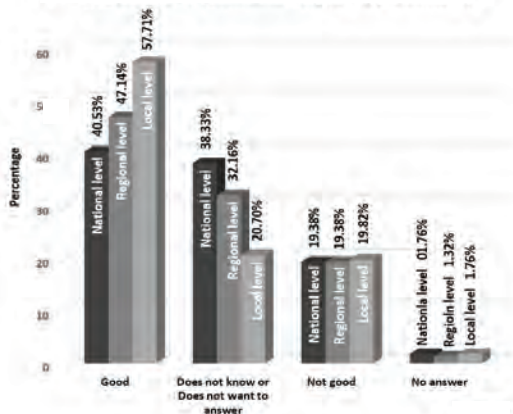
**30 Do you believe messages and/or do you try to check the content?**



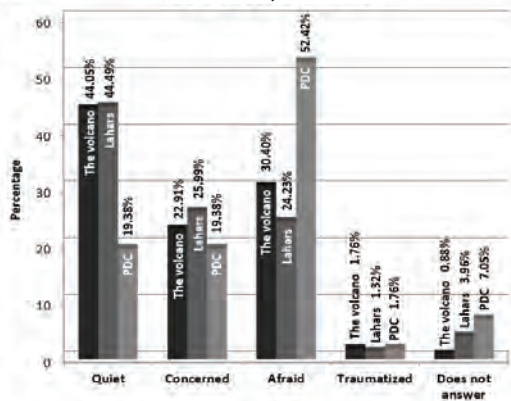
**31 Where from do you expect early warning?**



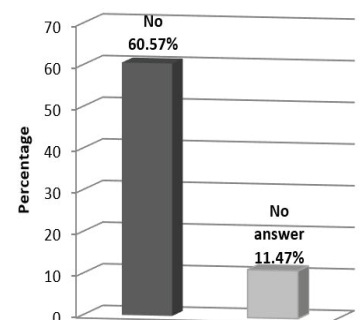
**32 Appreciation of government's help for preparedness:**



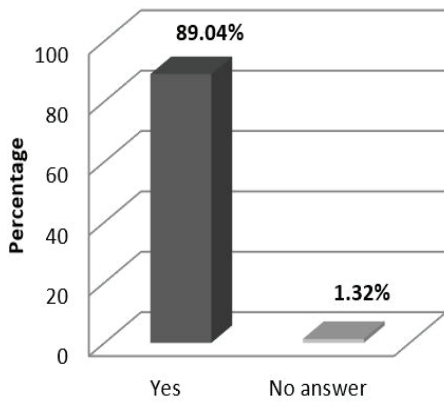
**33 How do you feel about the volcano, lahars, PDCs?**



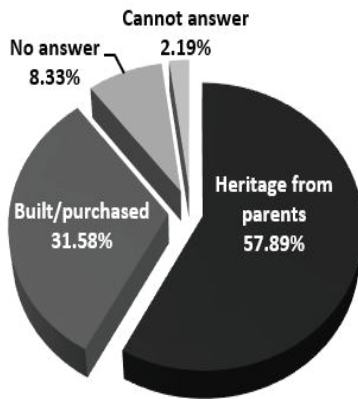
**34 Do you follow any rituals?**



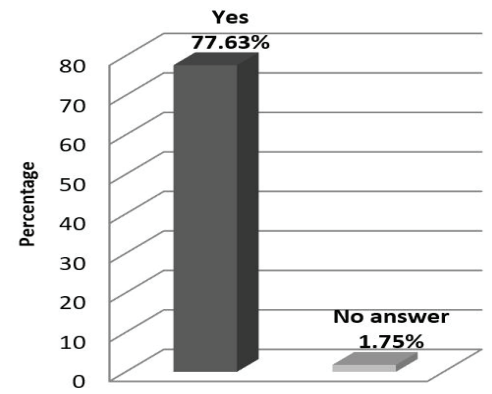
1 Do you own the house?



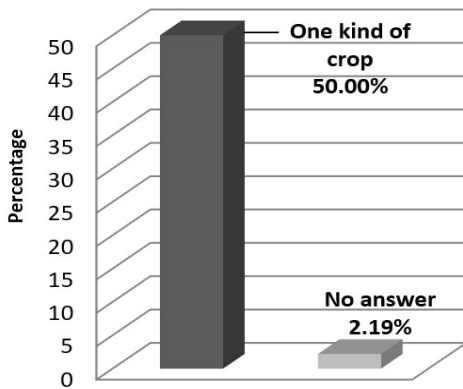
2 How did you get the land?



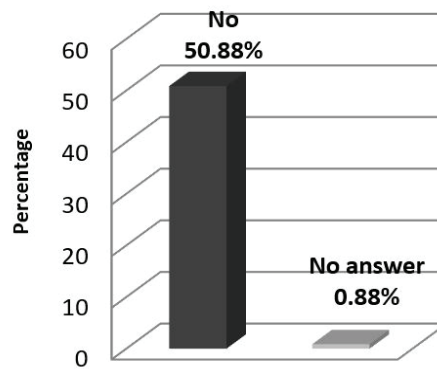
3 Do you own a garden, land or a forest?



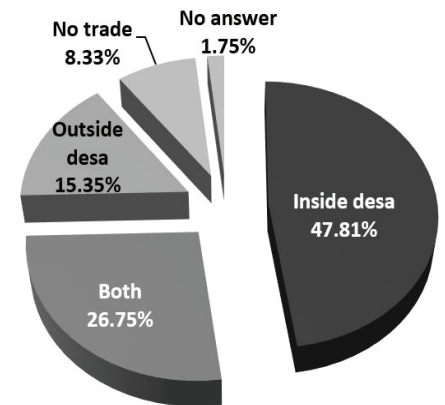
4 How many crops do you harvest?



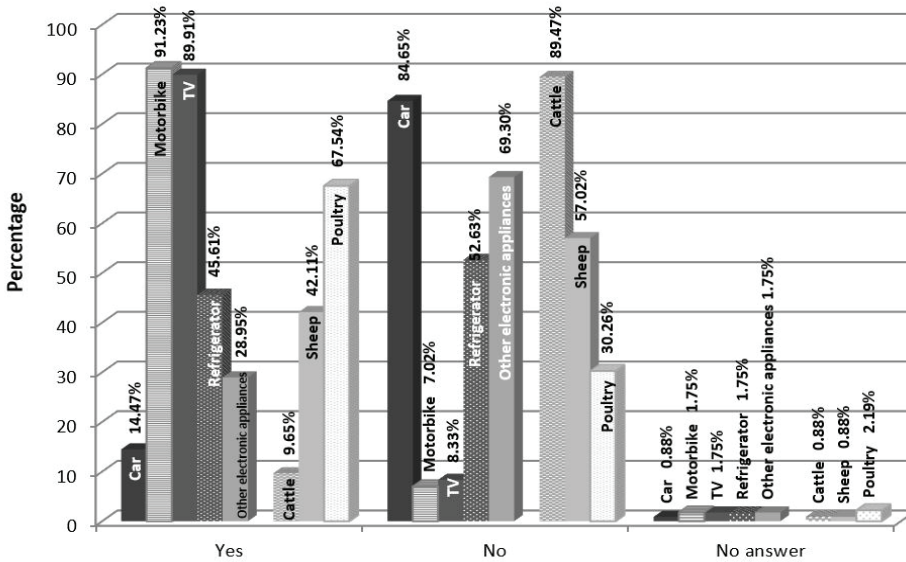
5 Is there any crop storage facility?



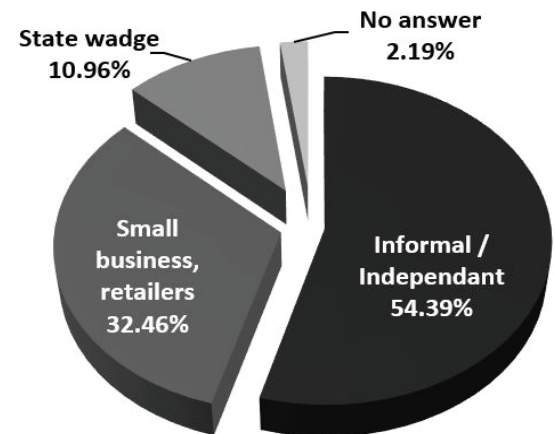
6 What kind of economic exchange?



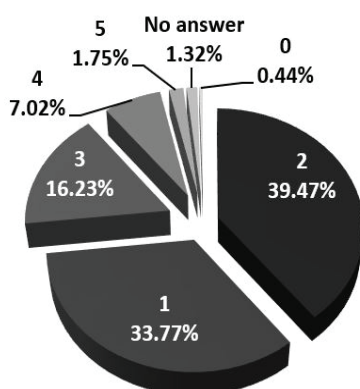
7 Do you own: car, motorbyke, appliances, animals?



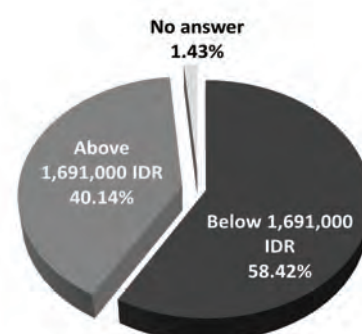
8 Type of livelihood and source of resources



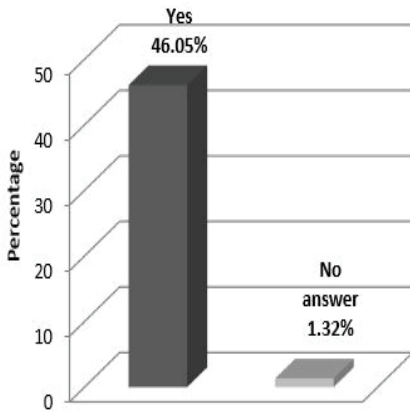
9 How many people contribute to the family resources?



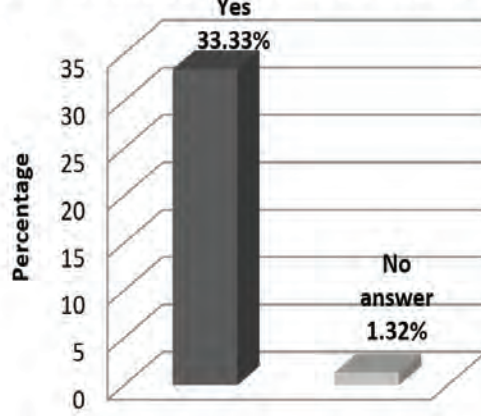
10 Is the household monthly income above or below the minimum salary IDR threshold?



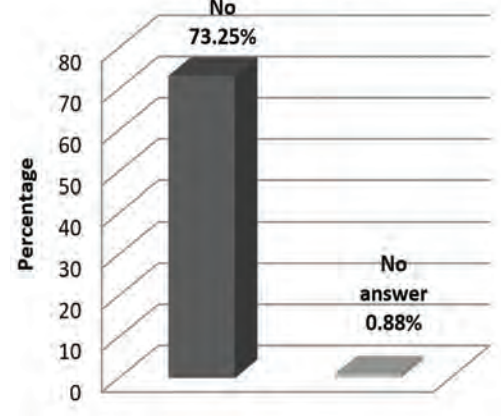
11 Are you in debt?



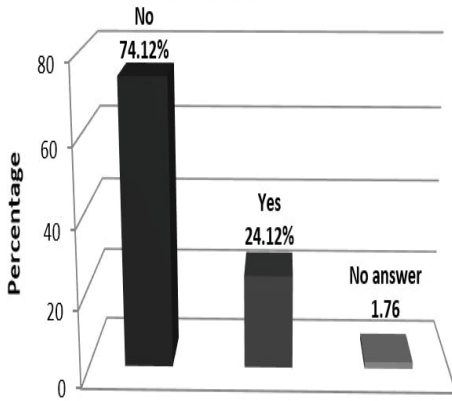
12 Are you insured?



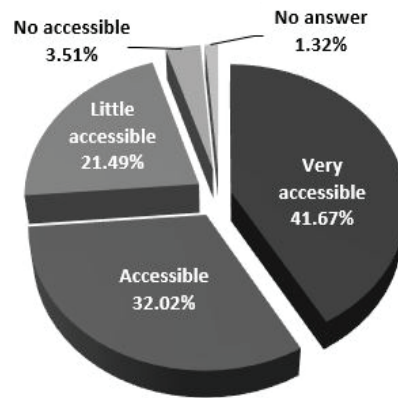
13 Do you benefit from microloans?



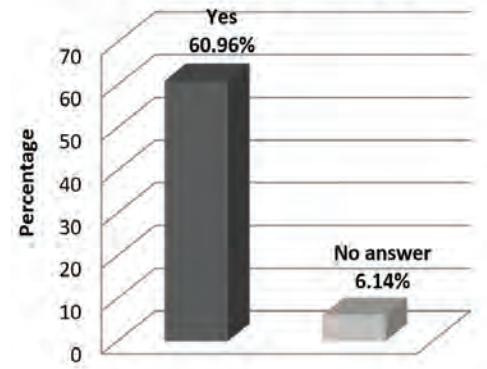
14 Can the family rebuild the house in case of disaster?



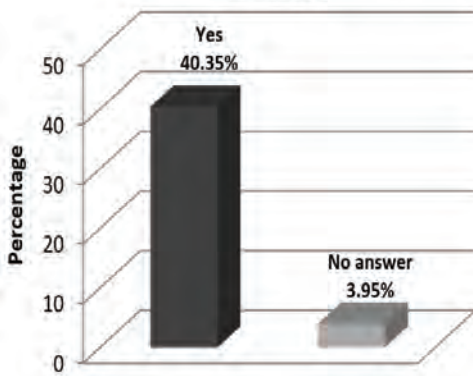
15 Do you have access to evacuation facilities?



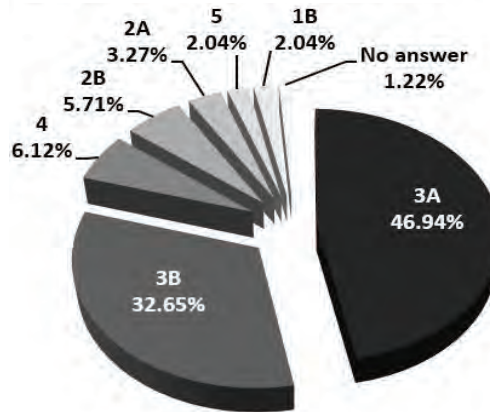
16 Is there any civil protection work against volcanic phenomena?



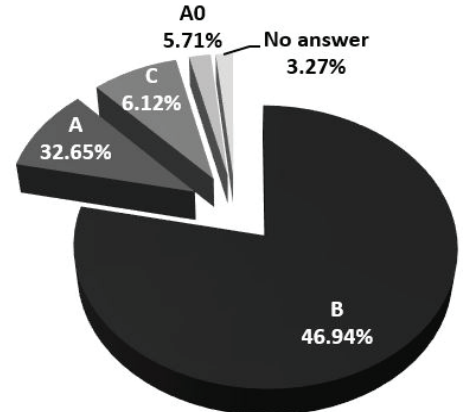
17 Do you or does your family suffer from any handicap?



18 Structural typology of houses



19 Physical vulnerability of houses



ESD Fig. 8B