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Perception of risk for natural hazards in Campania Region (Southern Italy)

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ABSTRACT

As far as the European continent, Region Campania in Southern Italy presents an almost unique combination - in terms of both variety and intensity-of potential risks for the residents: this densely populated area is actually most notably exposed to hydrogeological (flood and landslides), seismic, volcanic hazards In such a setting, alongside with an up-to-date scientific approach to risks analysis and the constant update of emergency plans, it is of paramount importance that a "risk awareness culture" should be developed by the residents. In order to maximize the effectiveness of the communication campaigns to support and improve such a culture, a study of risk perception has been carried out in 12 municipalities and 2 territorial unions of Campania Region. Different areas have been examined, the overall exposure of each almost always being characterised by a prevalent specific risk: seismic, volcanic, hydrogeological. The results of this surveys show that the historical memory has a crucial role on the hazards perception. It's also worth of noting that few communities consider that they have been sufficiently well-informed by civil protection agencies and/or authorities about the natural hazards specific to their area and the practical procedures for evacuation. To overcome these deficiencies emergency plans should be designed, developed and practised through the collaboration of all key stakeholders, from civil protection authorities to the residents communities.

1. Introduction

The Campanian Region of Southern Italy is exposed to several natural hazards, including floods, landslides, earthquakes and volcanic eruptions. They range in frequency and size from common local events with limited impact (such as minor slope collapses) to rare large-scale events with at least regional consequences (such as a major volcanic eruption or large earthquake); they may occur individually or together, either by coincidence or through the direct triggering of one hazard by another (such as landslides triggered by earthquakes); and they have a cumulative impact on human activities at the social, political, economic, environmental and technological level.

Each hazard presents a risk that depends on the vulnerability and exposure of the territory and its population. Several studies that defined risk perception as combination of social, economic, cultural factors have been published [1,2] and references therein; [3–11]. Vulnerability and exposure are themselves determined not only by objective criteria, such as numbers of people and buildings and the type of hazard, but also by how a threat is subjectively perceived and evaluated [12–16]. Although early analyses of risk from natural hazards concentrated on objective criteria, risk perception has been gradually incorporated into more recent studies [11,17] and references therein), particularly for volcanoes [2,18–29] [3,7,9,10,30,31]; Favereau et al., 2018), for floods and landslides [32–37]. The perception studies, however, have tended to focus on individual hazards and comparatively few have addressed multi-hazard scenarios [38,39].

Under Italian Law (n. 225 of 1992 and n.100 of 2012), each municipality must have its own PEC (*Piano di Emergenza Comunale*, Civil Protection Emergency Plan). In Campania the PEC of each municipality is developed starting from national regional hazard zoning and based upon mitigation strategies. Thus volcanic emergency plans are based on the National Emergency Plan for Vesuvius [40]; seismic plans on the Campanian Seismic Classification [41] and plans for floods and landslides on the Hydrogeological Risk Plan for the Central Campanian Basin [42].

Vesuvius is the volcano with the most frequent historical eruptions

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in Campania. Famous for the Plinian eruption (~1 km^3 dense rock equivalent, DRE) that destroyed Pompeii and Herculaneum in 79 AD, it has since been intermittently active with sub-Plinian (~0.1 km^3 DRE) and effusive eruptions (~0.01 km^3 DRE). Its most recent activity began after nearly 500 years of repose with a sub-Plinian eruption in 1631 (< 0.5 km^3 DRE; [43], followed by virtually persistent effusive and small explosive eruptions until 1944 [44]). For comparison, Campania's two other active volcanoes have had only one confirmed historical eruption each, in 1302 from Ischia [45,46] and in 1538 from Campi Flegrei [47–49]. Direct experience of eruptions is thus limited to those who witnessed Vesuvius in activity in 1944.

The current National Emergency Plan for Vesuvius is the latest revision of the plan prepared by Italy's Department of Civil Protection (DPC) in 1990 and is based on a return to activity with a sub-Plinian eruption [40]) scenario. It zones the region around the volcano according to the threat to life and property. The immediate threat to life defines the Red Zone, which covers the 25 municipalities around the volcanic edifice that are exposed to: pyroclastic density currents and, secondarily, to tephra fallout and lahars (Fig. 1a). This area is surrounded by a larger Yellow Zone, which is exposed to tephra fallout able to trigger roof collapse (Fig. 1a; BURC 2015). During an emergency, residents in the Red Zone will be evacuated before the onset of eruption, to be relocated among 19 regions across Italy. If the amount of tephra fallout exceeds a predetermined danger level, Yellow Zone residents could also be evacuated during the eruption and transferred to refugee centres within Campania Region.

The Campanian Seismic Classification [41] recognizes four categories for zoning earthquake hazard (Fig. 1b), based on the likelihood that a given area will be affected in a 50-year time interval by an event that exceeds a given intensity, measured by the horizontal ground acceleration, a. The zones are: (1) very intense seismic events expected ($a > 0.25$ g), (2) intense seismic events expected ($0.25 > a > 0.15$ g), (3) intense seismic events may happen rarely ($0.15 > a > 0.05$ g), and (4) low-intensity seismic events may happen rarely ($a < 0.05$ g). In common with the rest of Italy, a map does not currently exist for seismic risk or vulnerability in Campania. The most recent major seismic event to have affected the region is the 1980 Irpinia earthquake (M = 6.9). As a result, only residents more than 45 years old are likely to remember the experience of such a large event.

The Hydrogeological Risk Plan for the Central Campanian Basin (*Piano Stralcio per l'assetto idrogeologico* [42]; defines the severity of hazards and risks from floods and landslides. It provides the basis for developing a practical planning tool for risk management and prevention. It defines five categories of risk from floods and landslides (none/absent, R1, R2, R3 and R4) by combining the probability that a hazard occurs with the damage it is expected to cause. Each municipality prepares its own plan (PEC) against the risk, including actions for delivering information to communities.

This paper present the results of a study of multi-hazard risk perception conducted while producing or updating PECs in 12 municipalities and two territorial unions in the neighbouring provinces of Napli and Avellino. Investigated hazards are: floods, landslides, earthquakes and volcanic eruptions. Together with an assessment of the risk perception, we have tried to evaluate the knowledge of the hazards of the inhabitants, their self-efficacy, their perceived information level and their preferred sources of information. The study focussed on floods, landslides, earthquakes and volcanic eruptions, with the aim of evaluating risk perception, knowledge of hazards, self-efficacy, preferred sources of information and the perceived quality of the information provided to communities.

2. Material and methods

2.1. Locations for hazard surveys

Our study areas (Fig. 2) are representative of the different levels and frequency of exposure to seismic, volcanic and hydrogeological (floods and landslides) hazards across Campania: eleven districts are along a SW-NE trend from Massa di Somma on Vesuvius to Santa Paolina, near Benevento, in the Southern Apennines; two districts from the Sorrento Peninsula to the island of Capri; and Forio on the island of Ischia (Figg. 1 and 2).

Most of the districts along the Vesuvius-Apennine trend are vulnerable to similar levels of flooding and slope movement but to different levels of volcanic and seismic hazard. Along the northeastern half of the trend, Altavilla, Pietrastornina, S. Angelo a Scala, Unione del Baianese, Roccarainola share similar variations in surface relief and are covered with mobile volcanic soils formed from tephra-fall deposits. They are thus subject to similar levels of hydrogeological hazards, from landslides and mud flows to torrential flooding along ravines (commonly exacerbated by human activity). They all belong to the seismic classification zone 2 (Fig. 1b) and are outside the principal zones of volcanic hazard, except part of the Unione Baianese that lies within the Yellow Zone (Fig. 1a).

At the north eastern end of the Vesuvius-Apennine trend, Santa Paolina (Fig. 2) is characterised by gentler variations in relief and more impervious soils than the neighbouring survey districts and so has been classified as an area of low hydrogeological hazard [42]. Volcanic hazard is low because it lies outside the Yellow Zone and far away to the Vesuvius (Fig. 1a). The seismic hazard, however, is high (seismic zone 1; Fig. 1b), because of its terrain and proximity to the tectonically-active Apennine chain, and the district was heavily damaged during the region's last major earthquake in 1980 (M = 6.9 Irpinia earthquake; [50–52].

Along the southwestern half of the Vesuvius-Apennine trend, Liveri, San Paolo Belisto and Lauro (Fig. 2) share the seismic and hydrogeological hazard classifications as their north eastern neighbours. However, they lie within the volcanic Yellow Zone and, in part, border the Red Zone (Fig. 1a) that is vulnerable to pyroclastic density currents. Finally, the districts of Massa di Somma and Sant'Anastasia are on Vesuvius itself and so lie well within the volcanic Red Zone (Figg. 1a and 2). Although vulnerable to local volcano-tectonic earthquakes, the seismic magnitudes are typically modest (4 or less) and so they remain in the seismic classification zone 2 (Fig. 1b).

The Sorrento area and the Island of Capri are geomorphologically part of the Sorrento Peninsula, the southernmost limit of the Gulf of Naples (Fig. 2). They are outside the Yellow volcanic Zone (Fig. 1a) and have low exposure to seismic hazards (Zone 1; Fig. 1b) and medium to hydrogeological ones [42]. Slopes are steep, especially along the coast, with a poor soil cover. As a result, slope instability tends to occur as rockfalls, rather than the mudflows and landslips more common along the Vesuvius-Apennine trend.

Forio d'Ischia is a geothermal area in the western part of Ischia, an active volcanic island [53–58] in the Gulf of Naples and just outside the southwestern edge of Campi Flegrei (Fig. 2). The last eruption occurred on the eastern side of the island in 1302, after a quiescence of 250 years [45,46]. The island is dominated by Mt. Epomeo, which, with a summit at 787 m a.s.l., has steeper and less stable slopes to the north and west (and, hence, towards Forio) [42].

Although in a zone of medium-high seismic hazard (Zone 2; Fig. 1b), shallow earthquakes beneath the island have caused significant damage historically [59]. The most destructive occurred on 28 July 1883, with an estimated magnitude of 4.3–5.2 and Mercalli Intensity of IX [60]. It destroyed the town of Casamicciola, on the north of the island, killing 2333 people [59,61,62]. The most recent damaging event occurred on 21 August 2017, after the current study had been completed [63]; EMERGEO Working Group, [64].

2.2. The questionnaire and theoretical construct

The multiple-choice form of our questionnaire was based those developed and tested by similar studies in Italy [9,10,18] and elsewhere

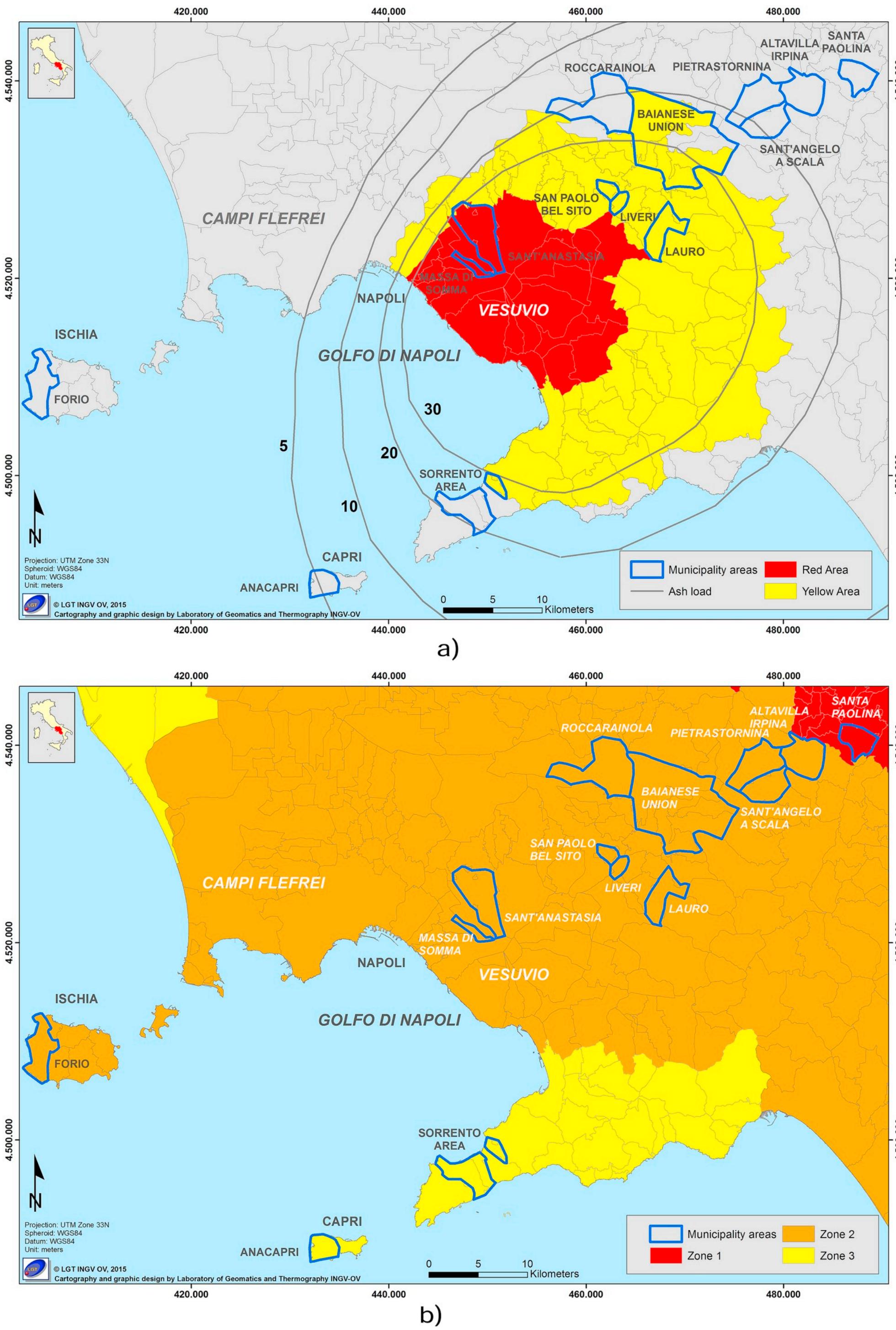

Fig. 1. a) Investigated areas on the map of volcanic ash load with an excess probability of 5% for Vesuvius (modified from BURC n.10 16 Feb. 2015). Refer to Table 1 for the details about administrative Districts. b) Investigated areas on the Italian seismic classification map as devised by DPC. Refer to Table 1 for the details about administrative Districts.

[3]). The answers to many questions were assigned a numerical score using the Lickert scale [65]. The About 5000 face-to-face interviews were conducted across the test locations (Table 1). The questions were organised into three sections:

- The introduction presented privacy statements and, to establish the background of respondents, collected voluntary data on age, gender, educational level and occupation.
- The central part of questions addressed awareness of hazards and risk in general, before concentrating specifically on earthquakes, landslides, floods and volcanic eruptions.
  Questions in this section were designed to assess knowledge of each hazard and perception of the related risk.
- The final section investigated levels of information and preparedness, with questions on self-efficacy, perceived information level and preferred sources of information.

All the questions were built adapted to our particular case the theoretical constructs developed and tested in similar researches conducted in Italy [9,10,18] and described in the following subsections where we have also highlighted in italic the indexes used in the following analysis.

2.2.1. Risk perception

Risk perception investigates how people consider the risk connected with a particular hazard and the concern about topics ranging from the perceived likelihood of an event and the seriousness of its consequences [7,9,10,18]. Participants were asked which hazards are likely to occur in their territories (called *Percipience* in our following analysis) from the list: landslides, floods, earthquakes, pollution, volcanic eruptions, blizzards, wildfires or other.

For each hazard we asked whether respondents considered their houses to be safe (in our following analysis called *Perceived Home Safety*; a choice of three answers, “no”, “don't know” and “yes”, with scores −1, 0, 1) and their concern about being affected by a hazard (in our following analysis called *Concern*; four answers from “not concerned” to “very concerned”, with scores 0–3). For seismic and hydrogeological hazards, we asked about the probability of such an event (in our following analysis called *Perceived Probability*; four answers with scores 0–3). For volcanic hazard we instead asked about the most probable effect of an eruption (choose as many as believed relevant from earthquakes, lava flows, ash fall, mud flow, rock falls, bradyseism, pyroclastic flows, or other).

2.2.2. Knowledge of the hazards

We evaluated the knowledge of hazards with questions based on information about being prepared for hazards, given in brochures distributed by Italy's Department of Civil Protection (www.protezionecivile.gov.it/jcms/it/cosa_fare_idrogeologico.wp for example). Respondents were asked to define each hazard (e.g., what is an earthquake?) and how to respond should it occur, in both cases choosing from a list of options with only one correct answer, as well as “don't know” and “other” (in our following analysis called *Knowledge of Phenomena*; *Knowledge of Behaviour*). The results were scored by the percentage of correct answers.

In order to parametrize the *Overall Knowledge* (*knowledge of phenomena* and *behaviour*) of each risk, we decided to make an average of the percentage of correct answers of all the aforementioned questions. In the same way we decided to make the average only on the knowledge of behavioural questions to have also a single behavioural parameter.

2.2.3. Self-efficacy

Self-efficacy is as an important variable for determining how well a community is able to take self-protective measures [7,66,67]. It is linked to perceived risk and the adoption of mitigating measures [18,68] and we have related it to how cooperation between neighbours may enhance or interfere with these measures. Participants were asked whether they felt confident in responding to a hazard (in our following analysis called *Control Level*; answers ranging from “none” to “full”, with scores 0 to 4), whether they had ever been exposed to a specific hazard (in our following analysis called *Experience*) and, if so, how would they describe their reactions (selecting an answer from “fear”, “confusion”, “indifference”, “control”, or “other”). We do not report data of these latter questions as they were not statistically significant, too few people did experience all the hazards in order to have a nice number of answers in every Municipality: besides earthquakes, where we had sample percentages at about 80–90%, for the other hazards only few tens of peoples (4–20, at average) have had an experience of them. They were also asked about the likelihood of collaboration during an emergency (in our following analysis called *Level of Collaboration*; four different answers: “no”, “don't know”, “it depends” and “yes”, with scores −1 to 2).

2.2.4. Perceived information level and preferred sources of information

To revise the PEC information plan, we asked participants about whether they already felt sufficiently informed about hazards (in our following analysis called *Information Self-Assessment*; “no”, “don't know” and “yes”, with scores −1 to 1), about *how they prefer to receive information* (“information brochures”, “audiovisual materials”, “public meetings”, “information office”, “other”) and from where they obtained information (in our following analysis called *Preferred Sources of Information*; “Municipality”, “District”, Istituto Nazionale di Geofisica e Vulcanologia” (INGV), “Civil Protection”, or “other”). Finally, we asked whether participants were aware of a local Civil Protection organization (in our following analysis called *Awareness of Organization*) or had ever been involved in evacuation exercises (in our following analysis called *Evacuation Exercises*), both questions having the choice of answer “no”, “don't know” and “yes” (scores −1, 0, 1).

2.3. Choice of the significant sample

We selected a representative number of people to be surveyed in each administrative district, based on demographic data from the 2015 Council Registers (Table 1). The number in each samples was chosen in order to obtain a maximum percentage error of 5% of the total population at 95% confidence level. Samples were not chosen randomly but selected to mirror the population distribution of gender, age (grouped into the ranges 20–34, 35–65 and 66–90) and location within each district. The age groups were selected to more or less reflect: high school students and recent graduates (20–34), people of working age (35–65) and retired (over 66). We excluded children from primary and secondary school because they need a special processing that was outside the target of the present study. Using 2015 data from the Registry Office 2015 (*Anagrafe*), we developed an algorithm to prepare named lists of the number of people in each age and gender category to be interviewed in each street. These lists were used by field operators to select interviewees.

2.4. Statistical elaboration of data

We developed a web-based system to combine the field data in digital form for analysis. The system is based on PHP (http://php.net/), a scripting language for dynamic web pages, and the powerful, open source object-relational database PostGreSQL (https://www.postgresql.org/). The system generated reports of the survey in a form targeted to the needs of civil protection agencies.

The system could also generate comma separated value (csv) files that were used to feed Micro$oft Excel spreadsheets. Such spreadsheets were then used to perform the actual analysis by means of both internal excel functions (correlations and unweighted linear fits, for example) or hand written Basic macros (weighted averages and fits, statistical errors etc.).

The level of participation and proportion of questions answered varied across the sampled districts. We extrapolated the percentage of answers of the samples to the whole populations: while doing so we calculated the standard error on populations in the hypothesis of a normal distributed population at 95% confidence level using one of the aforementioned macros. All the shown errors come from this estimation, error on derived variables were simply propagated with squared sum of the first derivatives. The numbers of questionnaires distributed and recollected are shown in Table 1.

For questions where Likert scales were available, we calculated the average value and relative standard deviation of the indicator. Such indicators have been then correlated with each other using the sample correlation coefficient embedded into Microsoft Excel to estimate the population Pearson correlation.

We also compared the percentage of the population aware of a given hazard with the exposed percentage indicated by superimposing the official hazard and population maps. When necessary, we updated

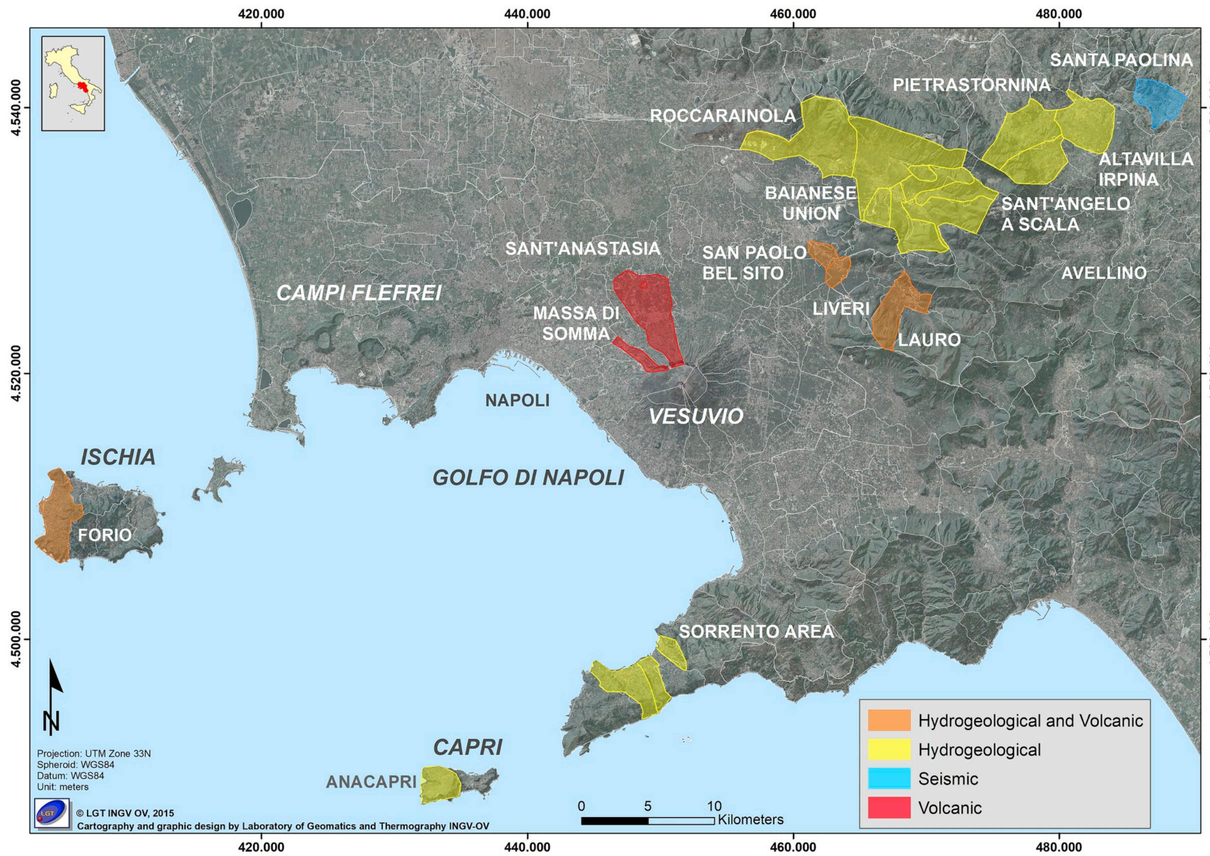

Fig. 2. Investigated areas. The territories of the districts are highlighted with colours corresponding to their main hazard. Refer to Table 1 for the details about administrative districts. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Table 1
Population is the number from Registry office 2015. The target population is the population in the selected range of 18–90 age. Questionnaires Distributed is the number of questionnaires that coincide with the number of the significant number chosen; Sample is the number of respondents. The two territorial unions are identified as "Unione del Baianese" (including the municipalities of Baiano, Avella, Sperone, Sirignano, Mugnano del Cardinale, and Quadrelle) and "Sorrento Area" (including the municipalities of Sorrento, Meta di Sorrento, and Sant'Agnello).

Municipality	Population	Target population	Questionnaires distributed	Sample
Massa di Somma (NA)	5736	4544	501	493
S. Anastasia (NA)	27921	21591	499	454
San Paolo Belsito (NA)	3497	2785	350	269
Sorrento Area (NA)	33908	27246	411	411
Lauro (AV)	3525	2894	352	229
Anacapri (NA)	6914	5570	387	387
Forio d'Ischia (NA)	17684	14008	378	279
Baianese Union (AV)	26693	21398	423	423
Liveri (NA)	1607	1302	320	223
Roccarainola (NA)	7121	5754	366	240
Santa Paolina (AV)	1293	1091	300	193
Altavilla (AV)	4281	3452	354	227
Pietrastornina (AV)	1574	1329	310	263
Sant'Angelo a Scala (AV)	735	617	254	169

published hazard maps that did not show the most recent events (especially for the more common hazards, flood and landslides).

3. Results

Due to the large amount of collected data, only a representative fraction of the results are shown here. The numbers of answers for instruction and occupation level were too few to be statistically significant in some districts and so we have not performed analysis on these factors.

3.1. *Volcanic hazard: knowledge and percipience of phenomena*

At least 60% of respondents recognised the meaning of a volcanic eruption in all but two of the study areas (Fig. 4). Moving northeast from Vesuvius, the percentage varied unevenly from 83% in the Red Zone, through 61–75% in the Yellow Zone to 70–96% beyond the Yellow Zone, while values of 83% (± 5%) and 97% (± 2%) were also recorded outside the Yellow Zone to, respectively, the west (Ischia) and south-south-west (Sorrento peninsula and Capri) of Vesuvius (Figs. 1a and 4). The lowest value of 57% (± 6%) occurred at Roccarainola, even though it is on the outer border of the Yellow Zone (Figs. 1a and 4). Proximity to Vesuvius thus appears to have had only a small influence on understanding the meaning of an eruption. Indeed, given the high level of participation for this question (74%), the overall average of 83% (± 5%; Fig. 4) indicates a good awareness of eruptions, regardless of age, gender and level of education.

In contrast, the proportion of respondents expecting an eruption generally declines with distance from Vesuvius, decreasing from 81 to 98% in the Red Zone to less than 1%, 14% and 20% beyond the Yellow Zone to the northeast, west and southwest respectively (Figs. 1a and 3).

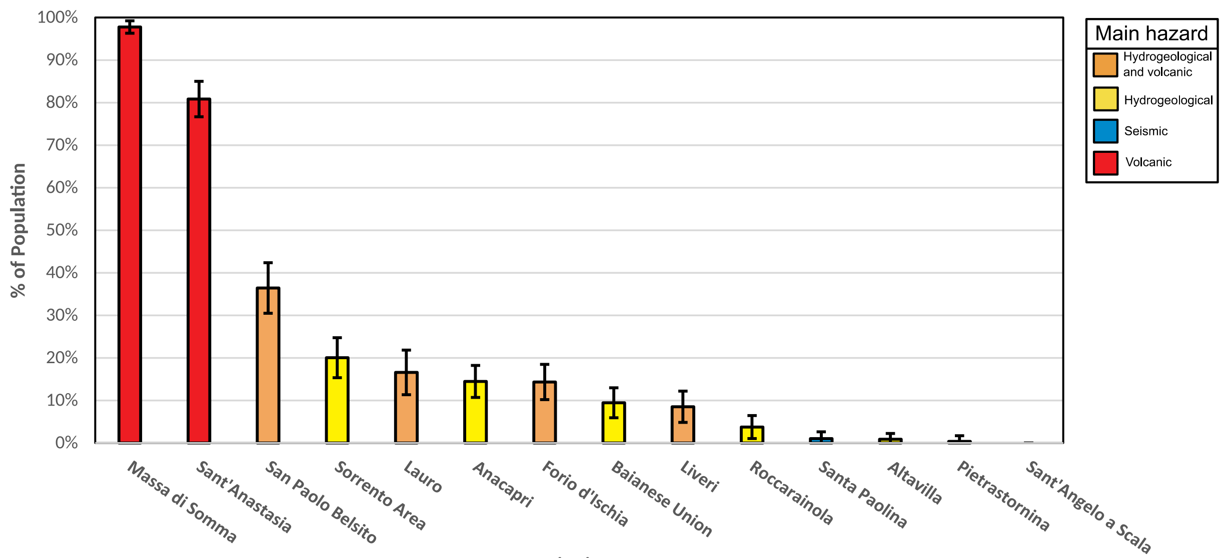

Fig. 3. Percentage of the population expecting an eruption (*percipience*). Colours correspond to the main hazard as in Fig. 2. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

The 14% (± 4%) at Forio d'Ischia is notable because Ischia is an active volcanic island, where an eruption last occurred in 1302. Instead, about one half of those interviewed (52 ± 7%) wrongly believed that Forio is included in the hazard areas of either Vesuvius or Campi Flegrei while two-thirds (66% ± 6%) had not participated in any kind of volcanic exercise (Section 3.4).

Among the three neighbouring municipalities by the border of the Red Zone, the expectation of an eruption varied from 9% (± 4%) at Liveri, through 17% (± 5%) at Lauro to 36% (± 6%) at San Paolo Belsito (Fig. 3). At Liveri, only a quarter (24% ± 6%) had participated in any kind of exercise, anyway the 64% (± 6%) could describe an eruption (Fig. 3) at the same time even in Roccarainola only 26% (± 6%) attended any kind of exercises and just 57% (± 6%) could describe an eruption; furthermore, a significant percentage (30%) refused to have their answers put on record or to give personal information.

3.2. Earthquake hazard: knowledge and percipience of phenomena

Fig. 5 shows a good correspondence between the seismic hazard classification of an area (Section 1.2) and the expectation of an earthquake among residents. Slight discrepancies are seen in only two cases: overrating the severity in Sorrento area and underestimating it in Pietrastornina. According to the 2015 *Catalogo parametrico terremoti italiani* (parametric catalogue of Italian earthquakes [69]; seismic events with Mercalli intensities (MCS) of 3 or more have been recorded in both areas in the past century. Such seismicity may be expected to favour the severity being overrated; hence only the results from Pietrastornina appear to be anomalous.

3.3. Hydrogeological hazard: knowledge and percipience of phenomenon

The results revealed a greater knowledge of landslides (about 80% or more), compared with floods (16–50%). Even so, the percentage of residents that think a landslide (Fig. 7) or flood (Fig. 8) is likely to occur

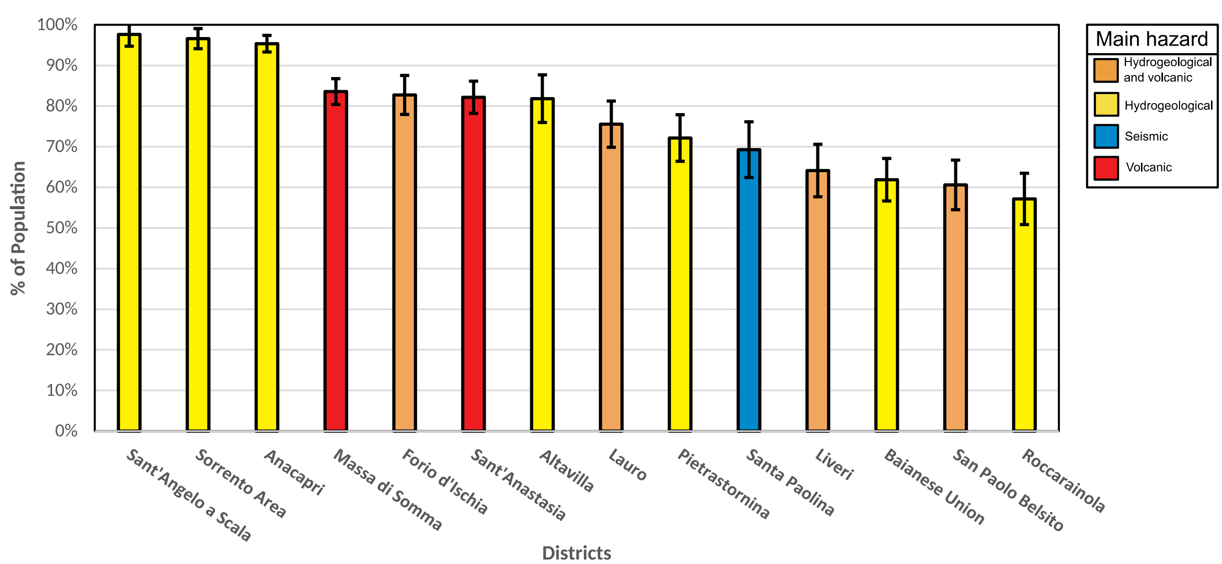

Fig. 4. Percentage of the population that exactly answered the question (*knowledge*): “What is a volcanic eruption?“. Colours correspond to the main hazard as in Fig. 2. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

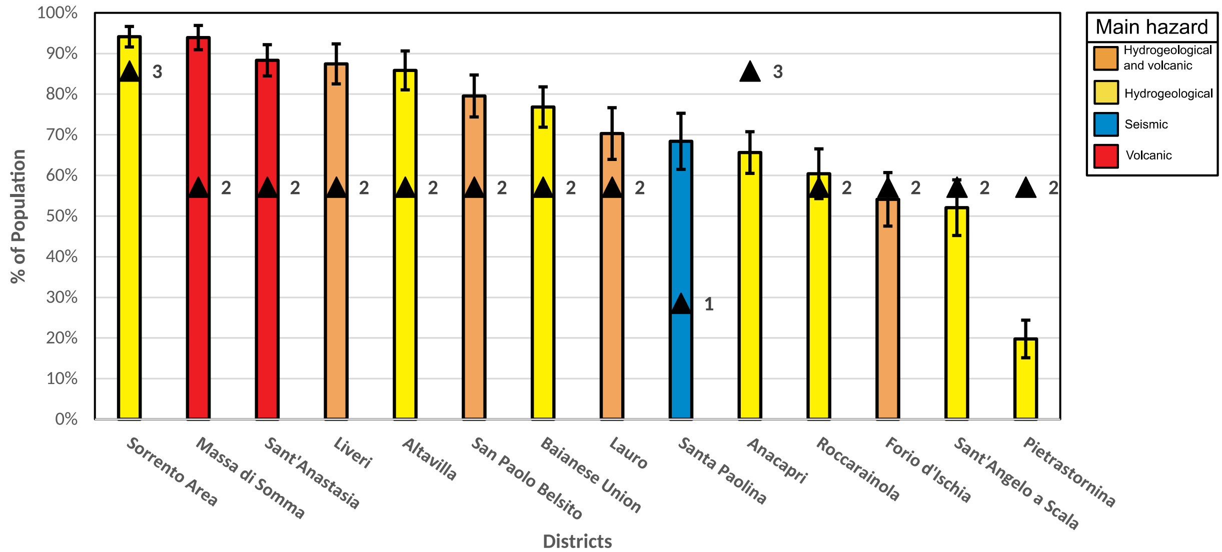

Fig. 5. Percentage of the population expecting an earthquake (*percipience*). Triangles refer to the national seismic classification (1 = high; 2 = medium; 3 = low). Colours correspond to the main hazard as in Fig. 2. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

is consistent with the number of people exposed to this risk as estimated in the PECs. For flooding, however, the results suggest that the severity is underestimated in Lauro, Massa di Somma and, especially in Anacapri, but overrated in Roccarainola (Fig. 8). At Roccarainola, in particular, the results indicate that 55% (± 6%) of residents expect a flood (Fig. 8) which is higher than the 20% of inhabitants exposed to flooding, according to PSAI risk maps (*Piano Stralcio per l'assetto idrogeologico*; Figs. 19 and 20a).

3.4. Perceived information level and preferred sources of information

When asked to evaluate the level of information received about natural hazards, very few respondents 13,1% (± 1,0%) think they have been correctly informed about their territory (Fig. 9) and most requested to be better informed by the authorities, notably by Province councils and Civil Protection agencies (Dipartimento di Protezione Civile, DPC; Fig. 10). Brochures received directly at home 69,5% (± 1,4%), and public meetings 56,1% (± 1,6%) were the preferred methods of receiving information (Fig. 11). As seen in Fig. 12, participation in evacuation exercises is quite low 24,6% (± 1,4%) and dominated by seismic evacuation (data not shown).

3.5. Comparisons and cross analyses of other acquired parameters

Figs. 13–15 compare how the belief that an earthquake, landslide or flood will occur (*Perception* described in Section 2.1.1) varies with *Experience* (Section 2.1.3) of the particular hazard. Volcanic hazards are not shown, because very few of the respondents had witnessed an eruption.

Direct experience appears to have no significant effect on expectations of an earthquake. The proportion expecting an earthquake remains similar at 52–95%, except at Pietrasantornina, where the number drops to 20%, even though 72% had previously been affected by seismicity (Fig. 13). In contrast, expectations of a landslide or flood appear to be positively correlated with previous experience (Figs. 14 and 15). The sensitivity to experience is remarkable, with expectations reaching peak values when the proportion of those with experience had reached about 1 person in 3 for landslides and fewer than 1 in 5 for floods.

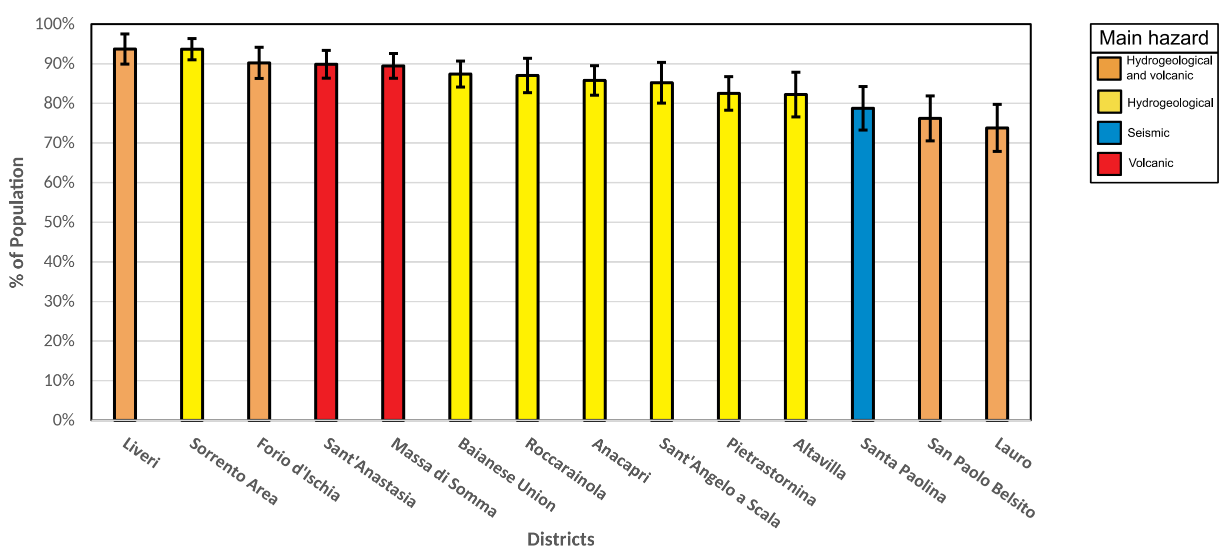

Fig. 6. Percentage of the population answers exactly to the question (*knowledge*): "What is an earthquake?" Colours correspond to the main hazard as in Fig. 2. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

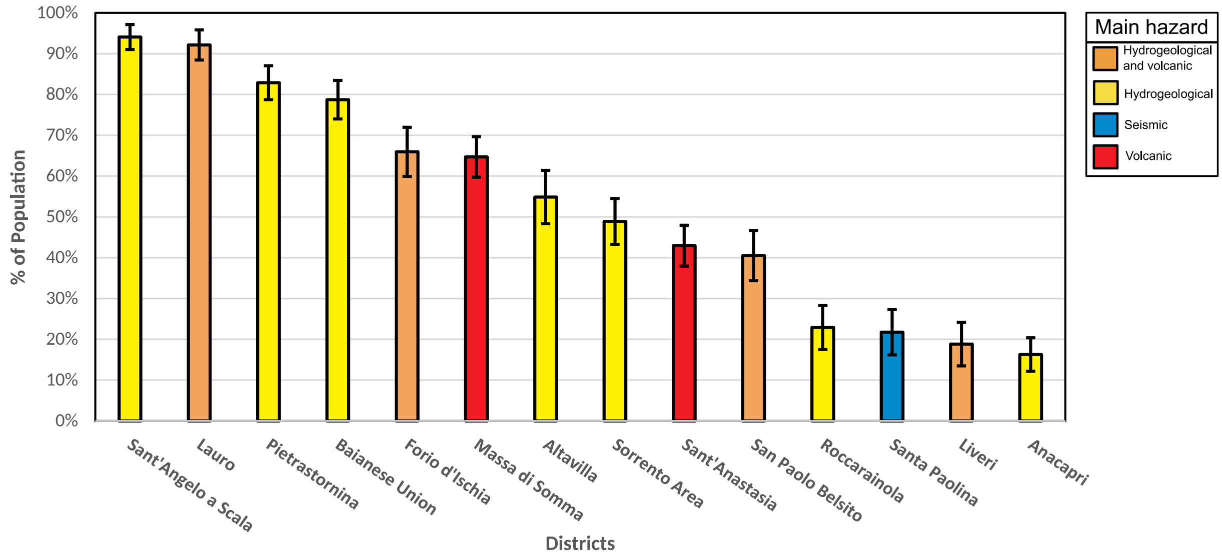

Fig. 7. Percentage of the population expecting a landslide (*percipience*). Colours correspond to the main hazard as in Fig. 2. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

In the two cases where a larger proportion of the population had previous experience of a hazard (66% for landslides and 35% for floods), expectations of a future event appear to have levelled off at close to peak values (Figs. 14 and 15). The levelling-off is a natural consequence of reaching high expectations at low proportions of previous experience; otherwise extrapolating the steep trends would yield impossible expectations of greater than 100% before reaching 100% experience. Even though expectations of a flood appear to level-off at lower values of 60–70% compared with more than 90% for landslides (Figs. 14 and 15), the overall shapes of the trends are sufficiently similar for them to be combined into a generic trend for hydrogeological hazard.

Figs. 16 and 17 show how knowledge of hazards and how to respond to emergencies varies with age and gender. Younger groups are better informed in both categories when all hazards are considered together, the behaviour-knowledge scores increasing from 50 to 55% for the 66–90 age group, to 65–75% and to 70–80% for those 35–65 and 20–34 years old, respectively (Fig. 16a). Similar trends persist when considering earthquakes and hydrogeological hazards separately, but, for volcanic hazards, the best scores were obtained among the 35–65 age group (Fig. 16b and c).

Comparing locations (Fig. 17b), knowledge is reasonably correlated among the youngest and middle-aged groups (r = 0.71), but poorly related between the oldest and middle-aged groups (r = 0.37). In contrast, the relative knowledge between men and women is similar across locations, with men tending to achieve scores as much as 20% higher (and 50% higher at Santa Paolina, where the lowest overall scores were recorded; Fig. 17a).

In order to understand if knowledge of phenomena influences in some way the three perception indexes described in Section 2.1.1, we correlated these indexes with the knowledge indexes for all the investigated Districts: results are shown in Table 2. From these data we see a very little correlation between the seismic perceived probability and the seismic behaviour knowledge, the remaining indexes seem quite uncorrelated.

Tables 2 and 3 compare the perception indices for all the study areas on concern for a hazard, probability of a hazard and safety of homes from a hazard. Apart from a weak correlation between the perceived

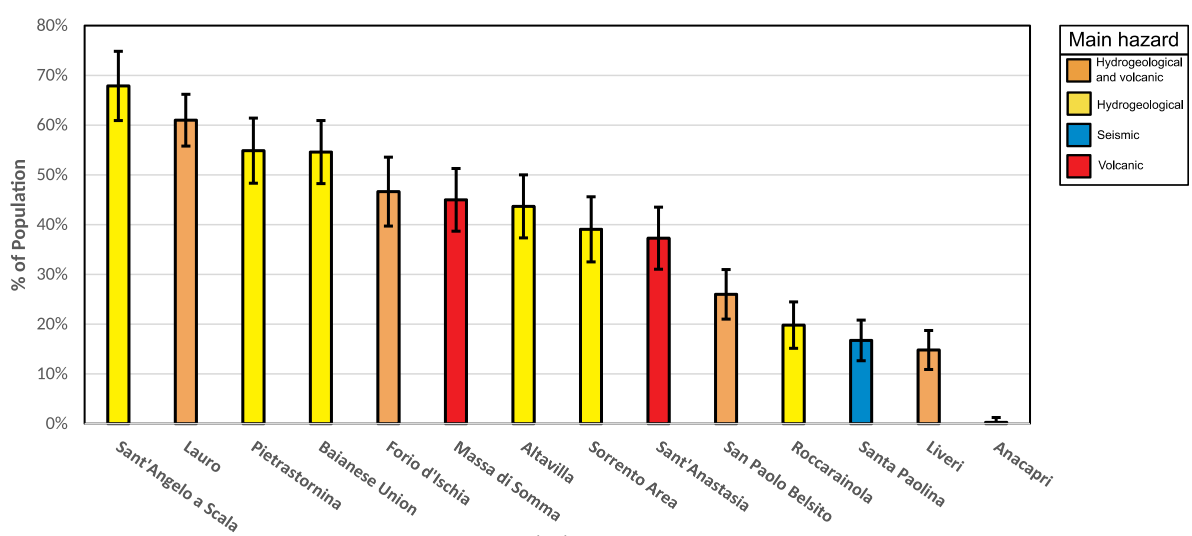

Fig. 8. Percentage of the population expecting a flood. Colours correspond to the main hazard as in Fig. 2. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

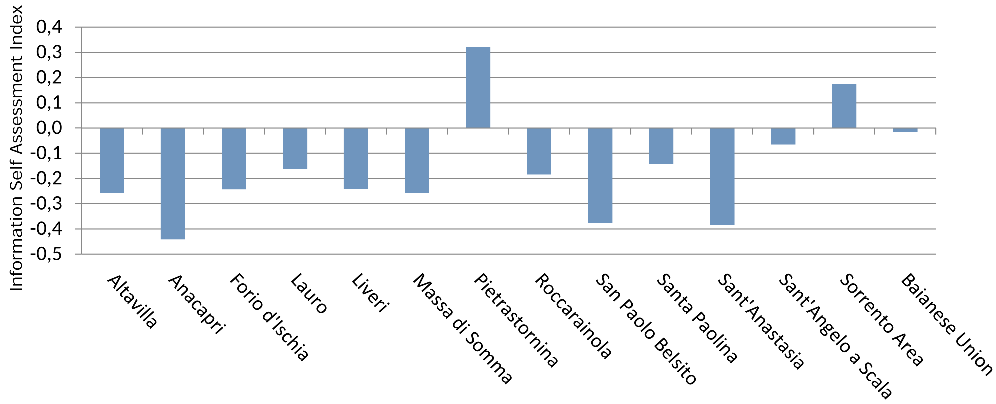

Fig. 9. People feelings regarding their correct information about natural hazards (Information Self Assessment). Negative and positive values indicate negative and positive answers respectively (−1 was "no", 1 was "yes"). Values towards 0 indicate undecided feeling (0 was "don't know").

probability of an earthquake and knowledge of how to respond, the indices appear be independent from each other (Table 2). The perceived probabilty of an earthquake is more strongly correlated with the level of concern (Table 3). All the hazards are seen as threats to homes (Table 3). The safety of homes, however, appears unrelated to the probability of an event or to the level of concern - apart, perhaps, from a weak anti-correlation between safety and concern for volcanic hazard (Table 3). The perceived threat from hazards to home safety may thus

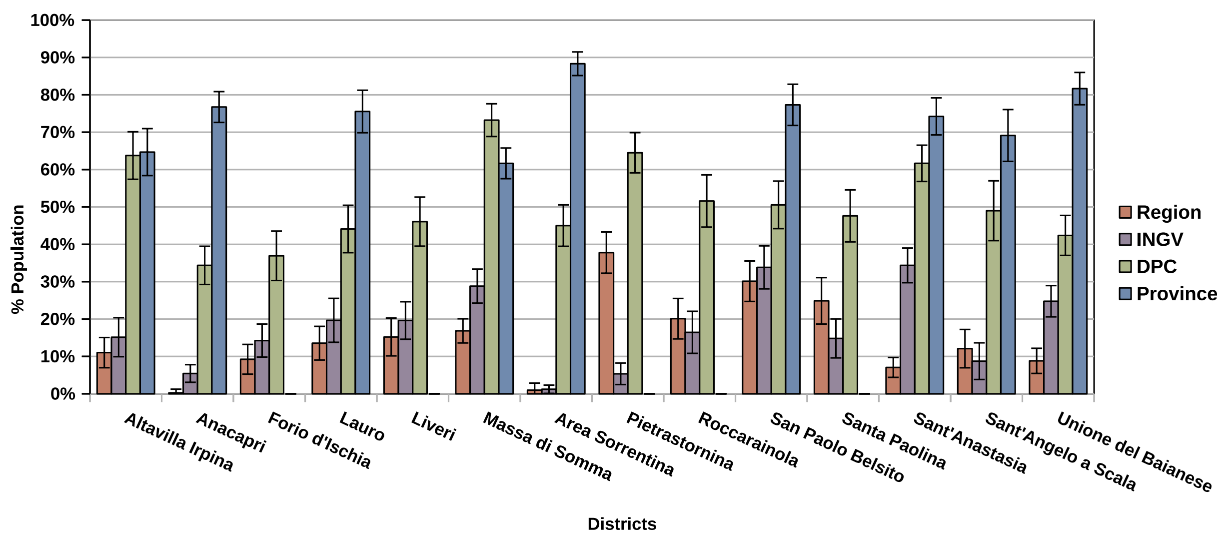

Fig. 10. Preferred sources of information.

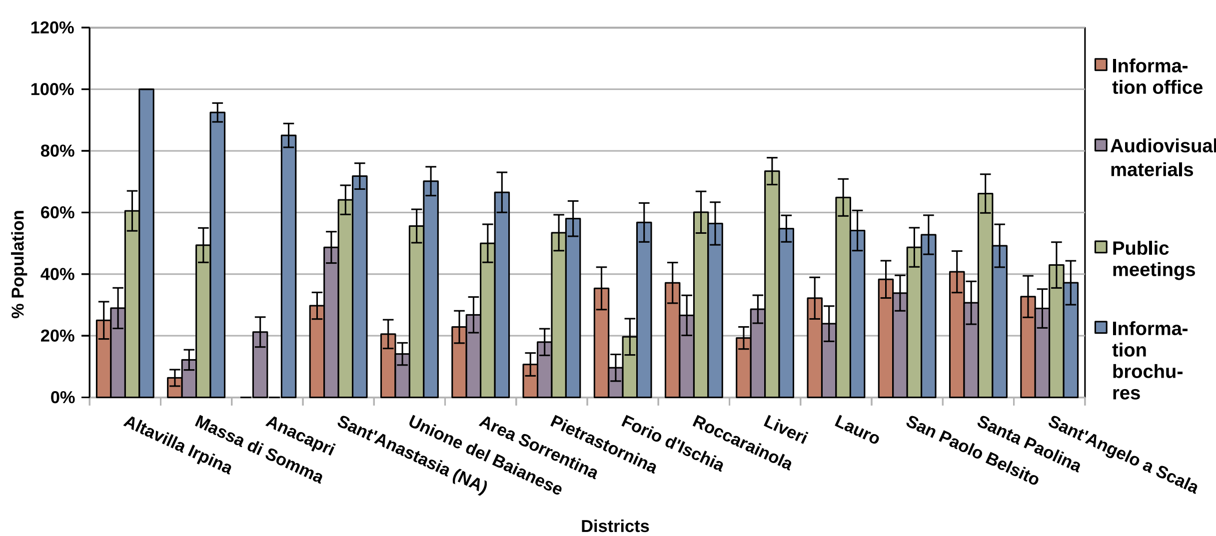

Fig. 11. Preferred information channels.

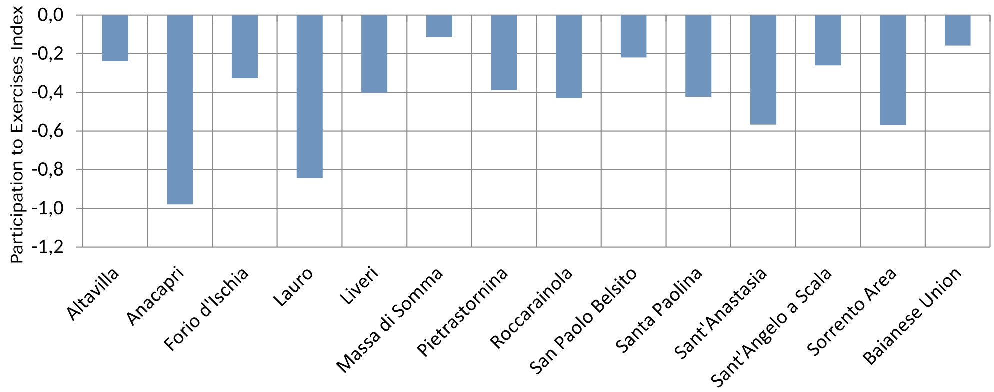

Fig. 12. Average level of attendance to natural hazard exercises for each District. −1 stands for "no", 0 "don't know", 1 "yes".

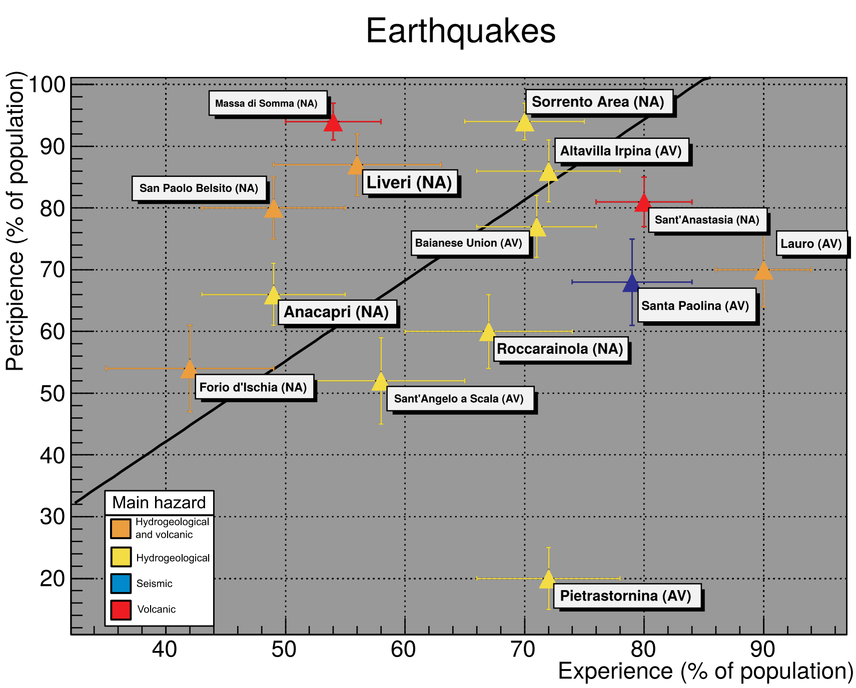

Fig. 13. Correspondence, for each administrative district, between the percentage of the population that experienced an earthquake (x-axis) and people expecting it (ordinate). Colours correspond to the main hazard as in Fig. 2. The black curve comes from a weighted best fit on the reported data using a linear model in the form: $P = a + b \cdot E$, where $a = -10 \pm 1$ and $b = 1{,}30 \pm 0{,}03$ with a correlation coefficient of 0,006, removing Pietrastornina the correlation coefficient raises to 0,17. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

reflect views about the status of houses in general, as well as awareness of their vulnerability, owing to little attention to preserving their territory and to increasing levels of urbanization (see also Fig. 18).

The three "concern" indices appear well correlated, suggesting either an overall concern about hazards, regardless of type, or that concern about one hazard raises concern about others (Table 3). Table 3 also suggests correlations between the perceived probability of an earthquake and concern for hydrogeological and volcanic hazards, and between the perceived probability of hydrogeological hazards and concern for earthquakes and eruptions.

None of the perception indices show any consistent relation with the self-efficacy indices for confidence in responding to an emergency ("control") and for the likelihood of collaborative behaviour ("collaboration") (Table 4). Similarly, no significant correlations are evident between either perception or self-efficacy and levels of information or experience of evacuation exercises (Table 5).

4. Discussion

4.1. Volcanic hazard

As might have been anticipated, communities within the Vesuvius Red Zone rated the probability of an eruption most highly. Further from Vesuvius, estimated probabilities dropped dramatically by more than a factor of two, even among groups with an awareness of eruptions almost as good as those within the Red Zone (Figs. 3 and 4). We attribute the abrupt change in probability to the fact that, during its last extended period of activity between 1631 and 1944, Vesuvius's eruptions were mainly effusive and affected only the volcano and its immediate neighbourhood, which broadly coincides with the limit of the Red Zone. Districts outside the Red Zone have not been affected so often by historical eruptions and so community perception of eruption frequencies is correspondingly lower. Delineation of the Yellow Zone is based on the distribution of tephra from a sub-plinian eruption with a magnitude that has not occurred since 1631. Hence, although hazard zonation may have favoured greater awareness of eruptions, it has not superceded community experience of activity in evaluating the probability of an eruption.

Estimated probabilities of eruption are also low even on active volcanoes outside the Vesuvius Red Zone. Ischia, for example, has been active historically with its last eruption in 1302. Nevertheless, respondents at Forio d'Ischia appear to believe that their exposure to eruptions is included within hazard maps for Vesuvius. Such a view is incorrect and may well have been reinforced by the absence of a civil protection plan for the island and consequent lack of emergency exercises.

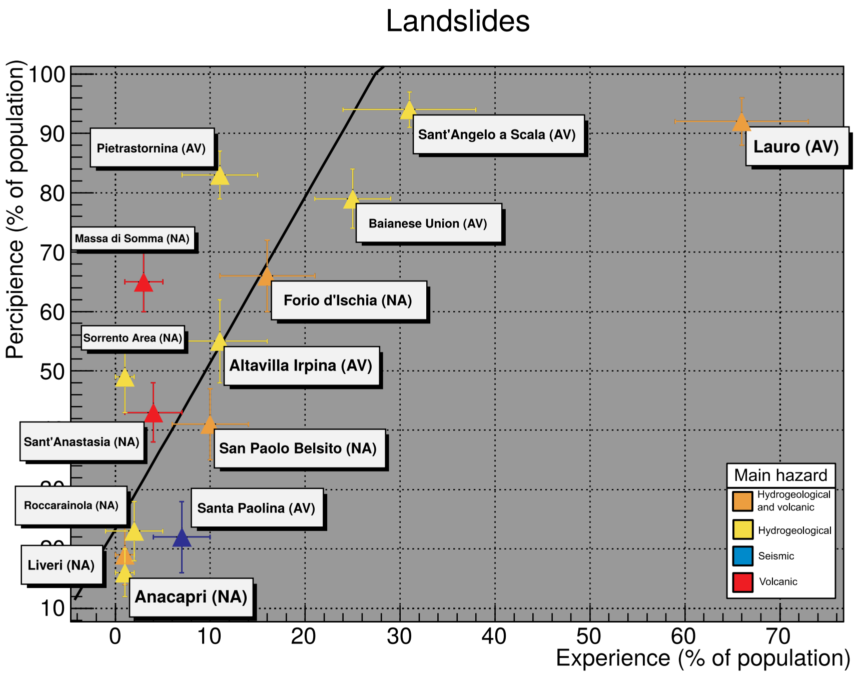

Fig. 14. Correspondence, for each administrative district, between the percentage of the population that experienced a landslide (x-axis) and people expecting it (ordinate). Colours correspond to the main hazard as in Fig. 2. The black curve comes from a weighted best fit on the reported data using a linear model in the form: $P = a + b \cdot E$, where $a = 2 \pm 3$ and $b = 2{,}8 \pm 0{,}4$ with a correlation coefficient of 0,72. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

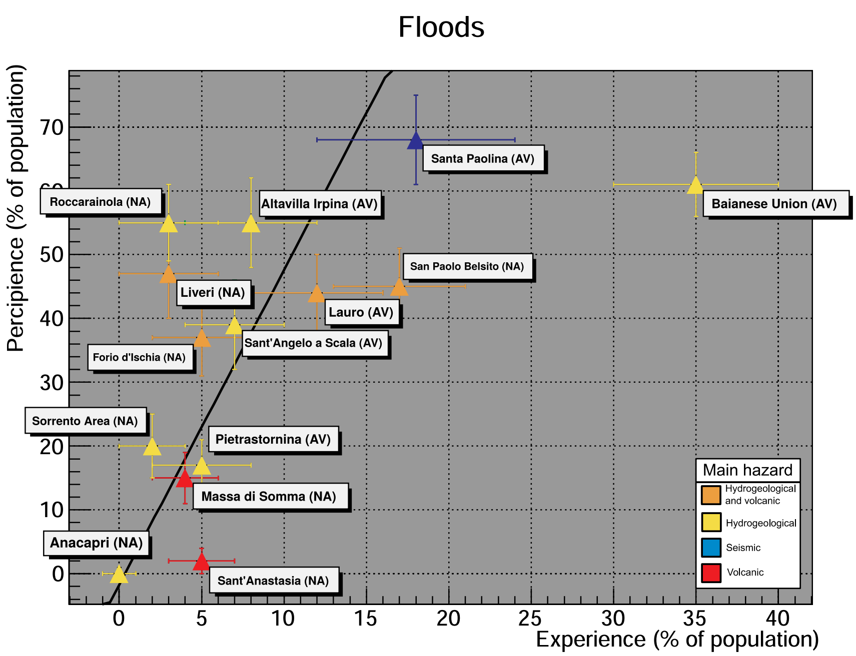

Fig. 15. Correspondence, for each administrative district, between the percentage of the population that experienced a flood (x-axis) and people expecting it (ordinate). Colours correspond to the main hazard as in Fig. 2. The black curve comes from a weighted best fit on the reported data using a linear model in the form: $P = a + b \cdot E$, where $a = -2 \pm 4$ and $b = 4{,}9 \pm 0{,}9$ with a correlation coefficient of 0,60. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Knowledge of volcanic hazards is greater among the 35–65 age group than for either older (66–90) or younger (20–34) respondents. In contrast, knowledge of seismic and hydrogeological hazards both increase systematically towards the youngest age group. The decrease in knowledge of volcanoes among the youngest group may reflect a lack of traction in current approaches to disseminating information to schools in particular and to the public in general.

4.2. Earthquake hazard

The expectation of an earthquake is reasonably high (55–95%) at all locations except Pietrastornina (20%) (Figs. 5 and 13), whereas all communities had good knowledge of what an earthquake is (Fig. 6). We believe the high values reflects experience of the 1980 Irpinia earthquake, which affected the whole of Campania. It is worth noting that respondents from Forio d'Ischia scored a low seismic risk perception at the time of the survey, which was conducted before the earthquake on 24th of August 2017 (Fig. 5). A survey today would probably show an increase in perceived risk.

4.3. Hydrogeological hazard

The perception of hydrogeological hazards is clearly correlated with direct experience of landslides and floods (Figs. 14 and 15). The relation would be even stronger for flooding at Roccarainola if we push the analysis beyond the boundaries of the PSAI data. Thus the PSAI does not include floods in all parts of Roccarainola in the past few decades (Fig. 19). If we take into account these excluded floods, the proportion of community exposed reaches 40%, a result consistent with general trends from our studies (Figs. 2, 8 and 150a). A similar result follows for

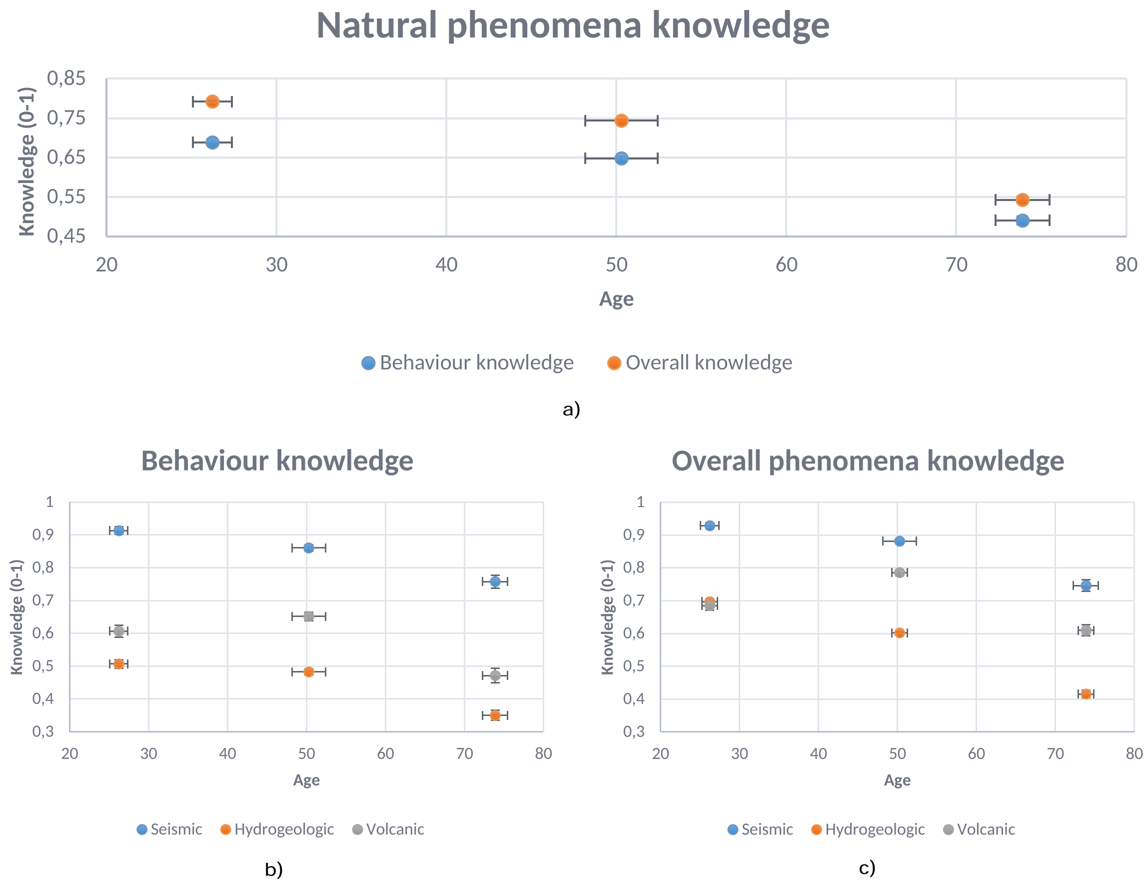

Fig. 16. Dependence of natural event knowledge on age. a) overall and behaviour knowledge by age, b) overall knowledge for each hazard, c) behaviour knowledge for each hazard.

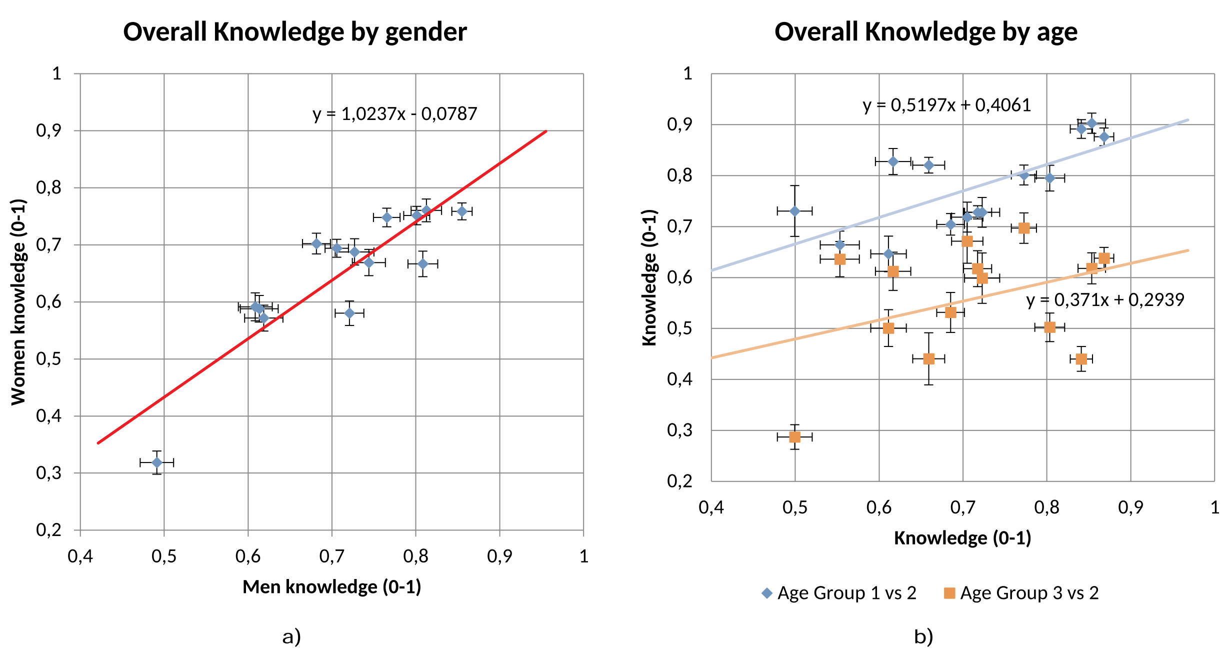

Fig. 17. a) relation between male and female knowledge for each District. The red line has a correlation coefficient of 0.88. b) relations between knowledge of age group 1 and 2 (blue dots, have age group 1 in ordinate) and between age group 3 and 2 (orange dots, have age group 3 in ordinate), both have age group 2 on x-axis. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Table 2
Correlation matrix between knowledge and perception indexes. Bold values refers to the correlations between the same hazard.

Correlation matrix		Concern			Perceived Probability		Perceived Home Safety		
		Seismic	Hydrogeol.	Volcanic	Seismic	Hydrogeol.	Seismic	Hydrogeol.	Volcanic
Seismic Knowledge	Overall	0,11	0,06	0,28	0,30	−0,05	−0,04	−0,12	−0,23
	Behaviour	**0,32**	0,20	0,41	**0,50**	0,11	**0,01**	−0,12	−0,27
Hydrogeologic Knowledge	Overall	0,23	**0,20**	0,29	0,36	**0,30**	−0,08	**−0,23**	−0,26
	Behaviour	0,23	**0,21**	0,27	0,36	**0,34**	−0,13	**−0,34**	−0,26
Volcanic Knowledge	Overall	−0,07	0,03	**−0,05**	0,24	−0,21	−0,14	−0,08	**−0,06**
	Behaviour	−0,26	−0,06	**−0,01**	−0,08	−0,38	0,32	0,10	**0,33**

Table 3
Correlation matrix of the perception indexes.

Correlation Matrix		Perceived Probability		Perceived Home Safety			Concern		
		Seismic	Hydrog.	Seismic	Hydrog.	Volcanic	Seismic	Hydrog.	Volcanic
Perc prob.	Seismic	1,00	0,35	0,09	−0,06	−0,34	0,83	0,67	0,64
	Hydrog.		1,00	0,06	−0,01	−0,41	0,58	0,48	0,60
Perc. Home Safety	Seismic			1,00	0,65	0,64	0,27	0,16	0,01
	Hydrog.				1,00	0,73	0,11	0,27	−0,07
	Volcanic					1,00	−0,21	−0,16	−0,51
Concern	Seismic						1,00	0,81	0,84
	Hydrog.							1,00	0,78
	Volcanic								1,00

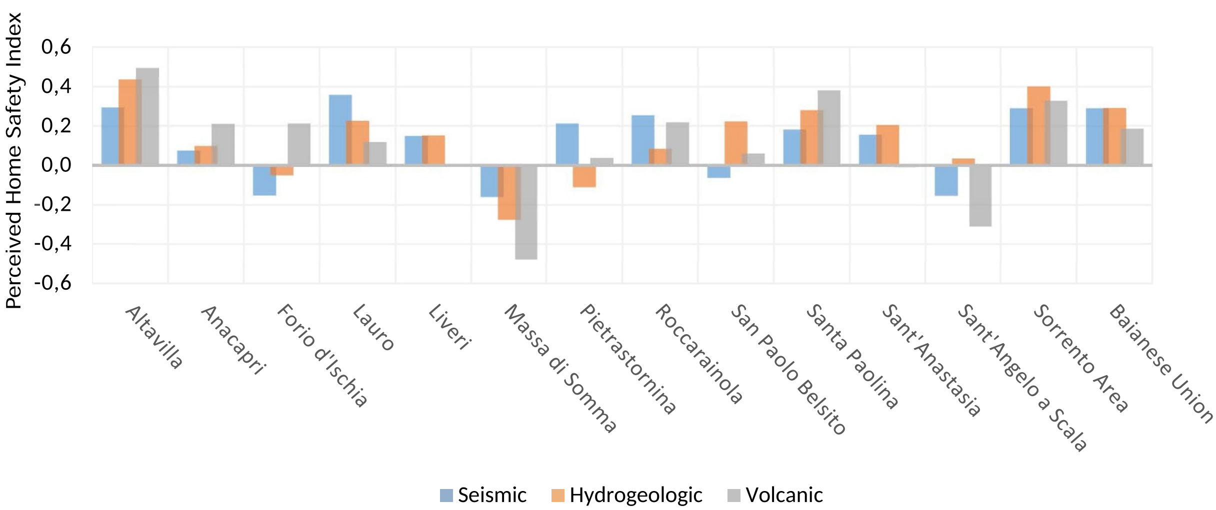

Fig. 18. Perceived home safety for each investigated District and each hazard. The index ranges from −1 (house perceived as not safe) to 1 (house perceived as safe), 0 indicating a "do not know" feeling.

Table 4
Correlation matrix between self-efficacy, perception and knowledge indexes.

		Control	Collaboration
Correlation Matrix	Control	1,00	0,31
	Collaboration	0,31	1,00
Perceived Event Probability	Seismic	−0,31	0,12
	Hydrog.	0,05	0,46
Perceived Home Safety	Seismic	0,01	0,46
	Hydrog.	−0,04	0,49
	Volcanic	0,16	0,22
Concern	Seismic	−0,39	0,29
	Hydrog.	−0,41	0,37
	Volcanic	−0,47	0,14
Seismic Knowledge	Overall	0,09	−0,29
	Behaviour	−0,03	−0,29
Hydrogeological Knowledge	Overall	0,40	0,10
	Behaviour	0,22	−0,14
Volcanic Knowledge	Overall	0,35	0,06
	Behaviour	0,05	−0,14

landslides when non-PSAI data are also included for Roccarainola (Figs. 7 and 20b).

Communities showed a much greater knowledge of landslides that floods (80% against 50% or less). The difference is most acute at Lauro, Massa di Somma and Anacapri and may be caused by ambiguity in classifying events and by lack of direct experience. For example, on 5–6 May 1998, heavy rainfall triggered a huge number of landslides [70]; in Quindici, neighbouring our study area of Lauro, 161 people were killed and considerable damage was suffered, leading to 93% (± 4%) of respondents at Lauro recognising landslides, compared with 42% (± 6%) for floods (data not shown). At Anacapri, however, the very low perception of flood hazard can most easily be attributed to a lack of direct experience in the municipality (Fig. 15) and to the low probabilities of both floods and landslides [42]; Section 1.2).

4.4. Informing communities about hazards

The results show that perception of a hazard and how to behave

Table 5
Correlation matrix between information, self-efficacy, perception and knowledge indexes.

	Correlation matrix	Information			Self-efficacy	
		Evac. Exer.	Inf. S.-a.	Awar. Org.	Control	Collaboration
Information	Evacuation exercises	1,0	0,16	0,18	0,02	−0,02
	Information self-assessment		1,0	−0,42	0,56	0,60
	Awareness of organization			1,0	−0,42	−0,35

		Perceived Event Probability		Perceived Home Safety			Concern		
		Seismic	Hydrog.	Seismic	Hydrog.	Volcanic	Seismic	Hydrog.	Volcanic
Information	Evacuation exercises	−0,09	0,40	−0,37	−0,19	−0,29	0,02	0,13	0,22
	Information self-assessment	−0,11	0,31	0,34	−0,02	0,06	0,02	0,10	0,05
	Awareness of organization	0,39	−0,22	−0,20	0,06	−0,04	0,30	0,50	0,36

		Seismic Knowledge		Hydrogeological Known.		Volcanic Know.	
		Overall	Behaviour	Overall	Behaviour	Overall	Behaviour
Information	Evacuation exercises	0,30	−0,38	−0,18	0,12	−0,44	−0,34
	Information self-assessment	0,05	−0,03	0,33	0,30	0,18	0,27
	Awareness of organization	0,45	0,49	0,08	0,15	0,07	0,07

during an emergency are systematically lower than knowledge of the hazardous process itself (Fig. 16, Table 2). Similarly poor correlations have been recorded by previous surveys in Campania [9,10,18,19] and in other parts of the world [7,23]. Communities in our survey appear to recognise the discrepancy themselves (Tables 2–4). Although information is provided by several official sources (Fig. 10), it is not obviously improving confidence in behaving correctly or collaboratively when a hazard occurs (Table 5). Few respondents had been involved in an emergency exercise (Fig. 12) and virtually all the communities felt they needed additional information (Fig. 9).

An immediate implication is that official information is either sufficient but inadequately delivered, or simply inadequate. In either case, official sources need to make greater efforts to ensure that correct and sufficient information is distributed to vulnerable communities about natural hazards and emergency responses. The data collected through the survey may provide guidelines to public authorities to maximize the

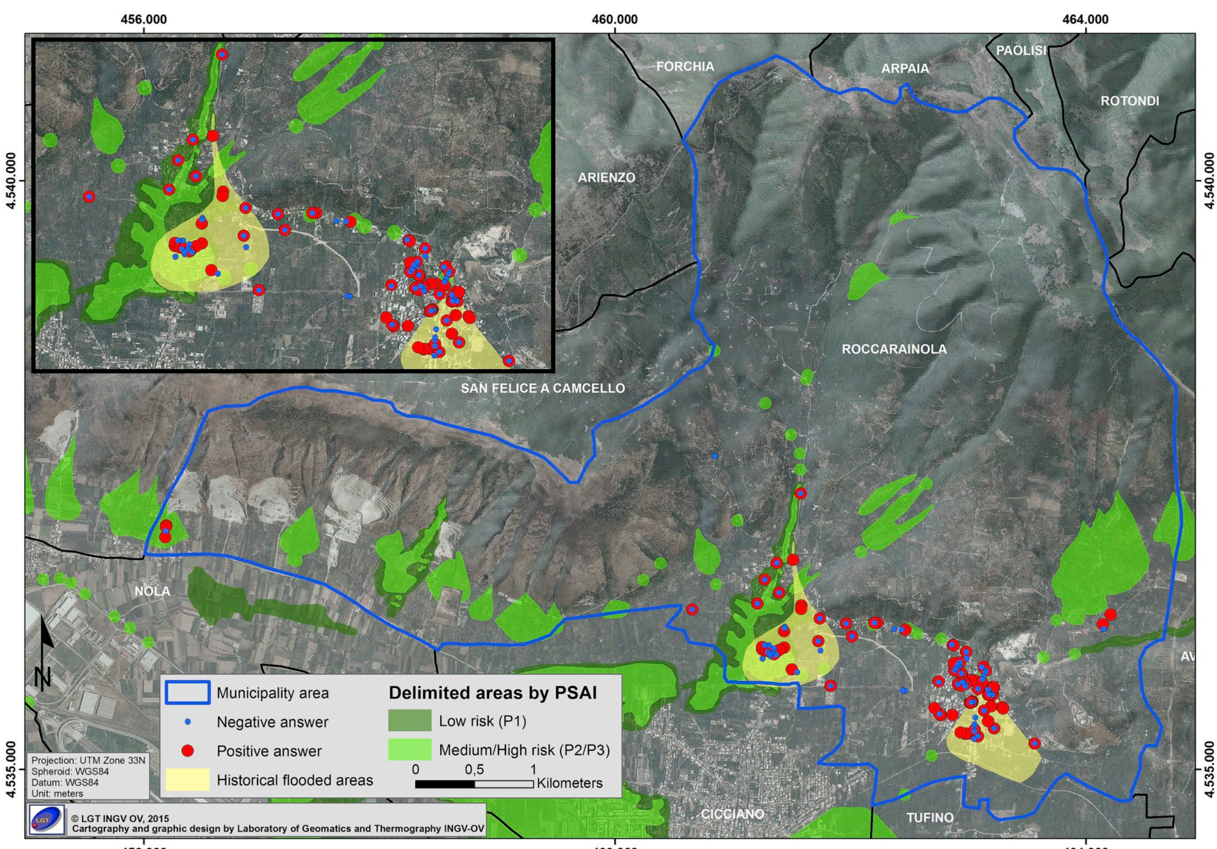

Fig. 19. Roccarainola Municipality. Green identifies the flooding risk areas as established by PSAI. Yellow are the areas where historical flood occurred. Red dots represent people expecting a flood event, blue ones peoples not expecting it. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

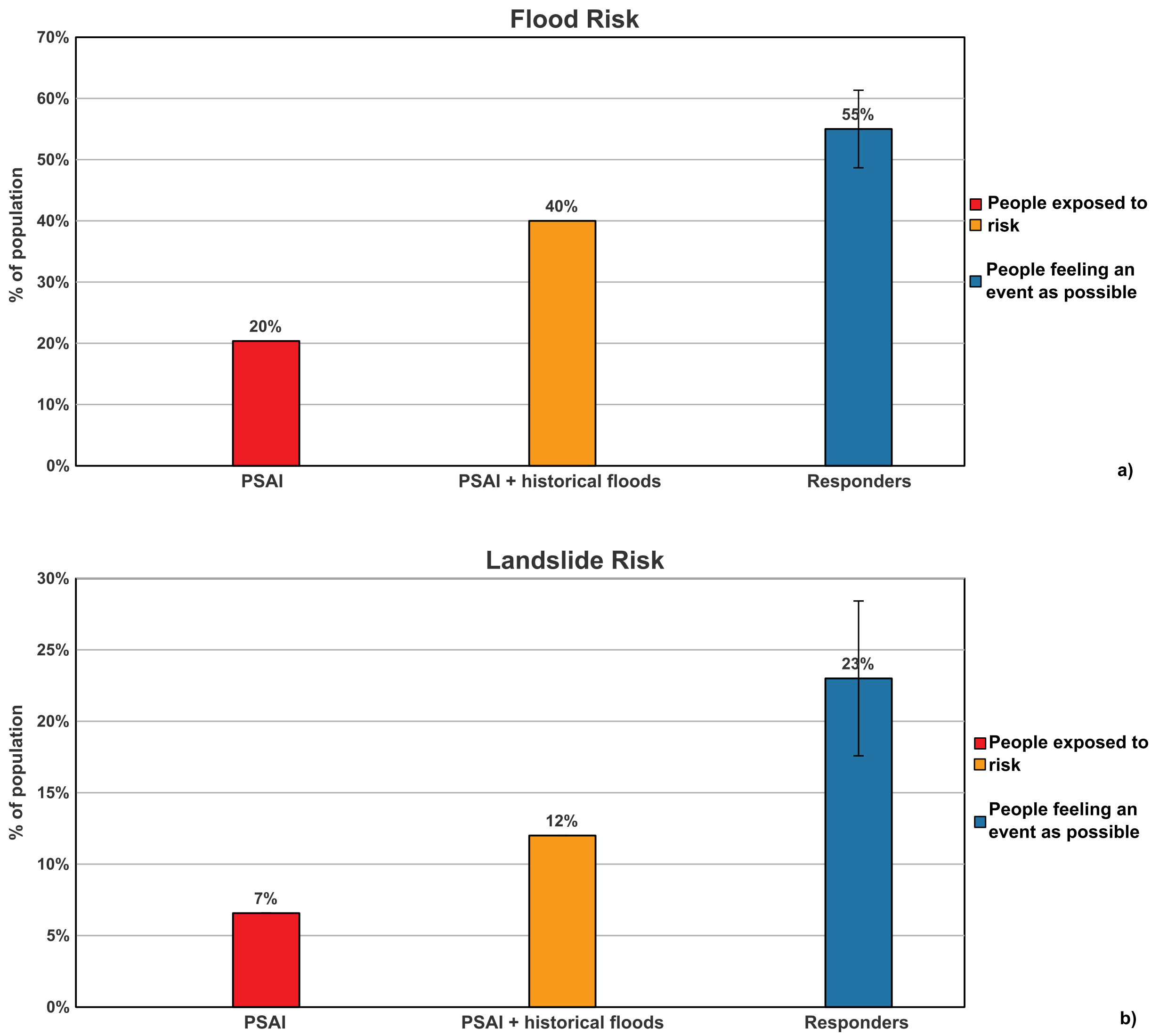

Fig. 20. Municipality of Roccarainola. Comparison between peoples feeling an event as possible (blue) and resident exposed to hydrogeological risk by PSAI (red) and by PSAI + historical flood (orange) for both flood (a) and landslide (b) risks. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

effectiveness of any information campaign: for a start, they can be used to understand which hazards and related risks are less familiar for the residents, and hence concentrate informations on these less-known issues. Ultimately, a better understanding of each separate hazard may increase the level of preparedness when multi hazard events occur. Even though information may increase theoretical understanding of a hazard, it may still not prepare communities for the full impact of an emergency. Helping the public prepare is an essential responsibility for the authorities and, increasingly, also for institutes dedicated to hazard research, because raising community awareness, preparedness and resilience is a strategic instrument for saving lives [11].

5. Conclusions

Our survey shows that communities are poorly prepared to respond to a natural hazard, even when they understand how a hazard behaves. This discrepancy applies to all the hazards investigated: earthquakes, volcanic eruptions, floods and landslides. It is therefore important that hazard warnings and evacuation measures are designed to accommodate the possibility that the real understanding of an emergency is less than that believed by the community itself. Properly communicating new procedures is also essential, as shown by requests from the survey respondents themselves. A simple strategy to meet both requirements for emergency plans to be co-developed and practiced by all key stakeholders, from vulnerable populations to the scientific community, local authorities and civil protection agencies.

Our results also provide a basis for understanding the inter-relations between hazards and their cumulative impact, rather than treating each hazard independently. Such a multi-hazard approach is more realistic and would favour the development of even more robust emergency procedures. Although not explicitly discussed, some of the authors are residents in the surveyed districts and their local knowledge helped to identify nuances in responses among communities.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijdrr.2019.101164.

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