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ORIGINAL ARTICLE

An approach to measure resilience of communities to climate change: a case study in Calabria (Southern Italy)

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Abstract
Climate change effects already represent a serious challenge for people and environment. In particular, changes in precipitation, temperature, and weather systems are increasing the occurrence frequency of natural phenomena such as floods and landslides with consequent negative impacts in exposure and vulnerability of population living in risk areas. Hence, it is important to assess the social vulnerability and the community resilience which describe the ability of social systems to prepare for, absorb, and adapt to risks induced by climate change. In two sample areas located along the Tyrrhenian side of Calabria (Amantea and Lago municipalities, Southern Italy), we performed a multi-criteria decision analysis (MCDA) of community resilience. Based on previous literature, we have selected five macro-indicators of social resilience (awareness, knowledge, information, trust, and social background). As sub-indicators for the characterization of these macro-indicators, we used the answers of the questions on climate change effects of a questionnaire submitted to citizens living in the sample areas, and, then, a specific weight was assigned to each sub-indicator, as well as to the macro-indicators. The multi-criteria analysis allowed to the classification of the studied areas in terms of an index of social resilience and to the individuation of the most influential macro-indicators for each of them. The results show that the two areas, which have similar resilience's values, are influenced by different macro-indicators: knowledge and awareness for Amantea and information and trust for Lago. The findings of this study can be considered very useful for the management of vulnerable areas to climate change, because they are able to underline the aspects needing attention. In fact, providing information about the nuances of the resilience of community exposed to risks may help decision-makers in adopting and implementing more effective preventive measures to mitigate negative effects of climate change, fitting on local characteristics.

Keywords Climate change impacts · Multi-criteria decision analysis · Social resilience · Southern Italy

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1 Introduction and background

In the last century, climate change strongly enhanced its effects, leading to a heavy increase in extreme events. Given the current trend, a further intensifying of those phenomena and their intensity, with inevitable consequences on territories and populations, is predictable (Collins et al. 2013; Gariano and Guzzetti 2016; Lehner et al. 2006; Madsen et al. 2014; Toreti and Desiato, 2008).

The Mediterranean Basin, lying in a transition zone influenced by both the arid climate of North Africa and the temperate and rainy air masses coming from Central Europe (Giorgi and Lionello 2008), is considered one of the most affected areas by climate change: rising temperatures and decreasing rainfall can significantly influence rainfall distribution both in time and space. In particular, several studies performed at regional scale (among them, Brunetti et al. 2012; Deitch et al. 2017; Caloiero et al. 2019) revealed a diffuse negative trend of yearly total precipitation and different tendencies among the seasons: negative in fall and winter and positive in summer. As one of the consequences, an increase in frequency of severe drought events has been estimated (Sirangelo et al. 2015). Moreover, Polade et al. (2017) highlighted that an increase in dry days is often associated with a positive trend in rainfall intensity, with a consequent major frequency of phenomena such as floods (Llasat et al. 2010) and landslides (Gariano & Guzzetti 2016). For all these reasons, the Mediterranean region has been identified as one of the most prominent "hot-spots" in future climate change projections (Giorgi 2006; Tuel and Eltahir 2020), and the Calabria region (Southern Italy), in the middle of the Mediterranean Basin, can be considered an interesting study area for the impacts of climate change.

In a scenario as such, it is mandatory to be aware of the vulnerability and resilience levels of communities affected by climate change effects with the aim to implement efficient environmental management strategies and thus to increase resilience as well as to reduce vulnerability, given the strict interconnection between these two aspects. Actually, vulnerability and resilience can be seen as two sides of the same problem (Ran et al. 2020). Vulnerability is defined as "the conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards" (UNISDR 2009). Resilience is "the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of the hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions" (UNISDR 2009). Many authors already approached the analysis of these two aspects considering them as a whole. Already in 2010, Nelson et al. claim that these concepts are strictly interlinked and artificially separated by scientific traditions. Noy and Yonson (2018) underline as the evolution of the concept of resilience subsumed this concept to that of vulnerability. Diaz-Sarachaga and Jato-espino (2020) consider vulnerability as a key factor of the resilience, and Khattri (2021) explores the differential vulnerability and resilience of earthquake treating these aspects as two sides of a same coin. Sung and Liaw (2021) propose a joint model to study vulnerability-resilience to natural hazards as well as Jha et al. (2021) for the study of Himalayan communities prone to climate change. Bergstrand et al. (2015) measuring community resilience and social vulnerability in US counties found a correlation between high levels of vulnerability and low levels of resilience, indicating that the most vulnerable counties also tend to be the least resilient.

From this basis, it is clear that a better understanding of both social vulnerability and social resilience has now become a crucial aspect for an appropriated environmental

management aimed to cope with disasters related to natural hazard. The real challenge of the last years is to find a really efficient way to quantitatively evaluate social vulnerability and community resilience to natural hazards (Ran et al. 2020). Furthermore, Miller et al. (2010) claim that there is an urgent need to translate the complex conceptual insights linked to vulnerability and resilience into operational assessment methodologies and that integrated vulnerability and resilience assessments are necessary and will represent a step forward.

The multitude of factors that determine the vulnerability or resilience of a particular community and the desire to determine the best path to measure these concepts has led the scientific community to the adoption of composite indices constructed through the synthesis of the different indicators referring to the dimensions of these concepts. Tapsell et al. (2002) proposed an index of social flood vulnerability—Social Flood Vulnerability Index (SFVI)—starting from the previous literature. It takes into account social characteristics (single parents, age older than 75 years, long-term illness) and four indicators of poverty (unemployment, overpopulation, lack of a car, lack of a house). The Social Vulnerability Index (SoVI) of Cutter et al. (2003) considers numerous social variables (health, age, ethnicity, unemployment, disposable income, structure of the urban fabric), all of them linked mainly to demographical and economic aspects. The authors analyzed the variables with the principal component analysis (PCA), in order to reduce the initial indicators. Dwyer et al. (2004) proposed a further index for the Australian territory, considering social indicators very similar to those considered by Cutter et al. (2003). Nevertheless, the authors underlined the importance of other social indicators—such as sense of community, emotional ability, trust in the authority, risk perception, knowledge of natural hazards, and preparedness of local administrators—that are difficult to quantify and for this reason discarded for their study. Rigel et al. (2006) utilized socio-demographic and economic indicators to quantify the vulnerability to storms, by means of the PCA analysis. Risk perception was added to the socio-demographic and economic indicators to perform an index of vulnerability to seismic risk by Armas (2008). Fekete (2009) still used the same kind of indicators, but he mainly focused on the validation of his proposed index, underlining that even if many proposals of social vulnerability indexes exist, very few are the proposal of their validation. Also, the index proposed by Carnelli and Frigerio (2012), for measuring seismic vulnerability, is based on demographics and economic indicators.

The SoVi index (Cutter et al. 2003) is the basis for many other subsequent analyses. Holand and Lujala (2012) proposed an adaptation of such index to the territory of Norway and, in their analysis, compared the original version of the index and the adapted one for evaluating it exportability to other territories. Yoon (2012) used the SoVi index for analyzing the vulnerability to natural disasters in the Gulf of Mexico. Koks et al. (2015) proposed an adaptation for the Dutch territory for the vulnerability to floods. deLoyola Hummell et al. (2016) used the index for the vulnerability to natural risks in the Brazilian territory. In addition to demographic data, de Brito et al. (2017) used information on the risk perception for their analysis on the vulnerability to floods in the Taquari-Antas Watershed (Brazil).

Conversely to the cited works, in the study of Carone et al. (2019), social vulnerability was considered an inverse aspect of social resilience. In this study, an approach based on a multi-criteria analysis, which considers also non-economic indicators, was proposed. Similarly, Antronico et al. (2020) proposed social indicators of knowledge and risk perception, in addition to the demographic ones, for an analysis focused on climate change and social perception in Southern Italy. Spielman et al. (2020) underlined how it is very difficult to consider "right" or "bad" a social indicator compared with any other impartial measure.

The authors analyzed the SoVi index (Cutter et al. 2003) and its methodology for evaluating the aspects that make an indicator as a good one.

This literature review highlights that in order to propose a good index aiming to evaluate social vulnerability and social resilience, the index should take into account the multi-dimensionality of the vulnerability concept, as well as the multi-dimensionality of the resilience concept and the related risk perception. Starting from this perspective in this paper, we suggest a methodology reproducible and transferable, with the purpose to measure the social resilience of populations prone to climate change considering resilience as an inverse aspect of vulnerability, strictly linked to this last one.

In the work, we propose an approach based on the construction of a concise index of social resilience calculated by means of macro-indicators able to provide information on dimensions linked to the following aspects of the studied communities: (i) awareness of the problem, (ii) knowledge of the link between climatic phenomena acting in this century and the problem, (iii) trust in institutions, (iv) information, (v) and social characteristics. As underlined by Dwyer et al. (2004), these macro-indicators are extremely important for evaluating the resilience of populations prone to natural disasters, and, conversely to those authors, we overcome the difficulty to quantify them by combining a common tool for the data collection on social studies, a questionnaire, and a multi-criteria decision analysis (MCDA). Indeed, the delivering of a questionnaire to a population is very easy to employ (Corbetta 2015a) and allows for the retrieval of a good amount of information in a time-saving manner. Moreover, the questionnaire is universally recognized as the most suitable tool for collecting, analyzing, and interpreting social data for specific topics, regardless of the selected delivery mode (Kelly et al. 2008; Bird 2009). In recent literature, there are many examples of survey questionnaires used to ensure the selection of social factors influencing social vulnerability and community resilience to natural hazards as comprehensive as possible and adherent to the scale of survey (Kuhlicke et al. 2011; Kusumastuti et al. 2014; Box et al. (2016) ; Cerchiello et al. 2018; Dumenu and Takam Tiamgne 2020; Lottering et al. 2021 among others). In addition, some surveys related to social vulnerability and community resilience assessment utilize the Delphi method which is a survey technique for quality indicator selection based on expert judgments collected through questionnaires (Yoo et al. 2011; Wu et al. 2016; Fatemi et al. 2017; Pei et al. 2019 among others). At the same time, the MCDA analysis allows for a quick evaluation of multiple dimensions, as the social macro-indicators here considered. Both these aspects make the proposed approach able to evaluate crucial aspects of community social resilience, often neglected in previous studies, in favor of socio-demographic factors. The methodology was applied to a database deriving from two municipalities located in Calabria (Southern Italy), Amantea and Lago. The territories of the two municipalities are affected, although with different risk levels, to a series of natural phenomena (landslides, floods, and sea erosion), and, consequently, climate change will cause a decrease of resilience of the population living in these areas, as well as an increase in exposure and vulnerability.

2 Material and method

2.1 Study area

The study area is represented by the municipalities of Amantea and Lago (Cosenza province), located along the Tyrrhenian side of Calabria (Fig. 1). The territory of the

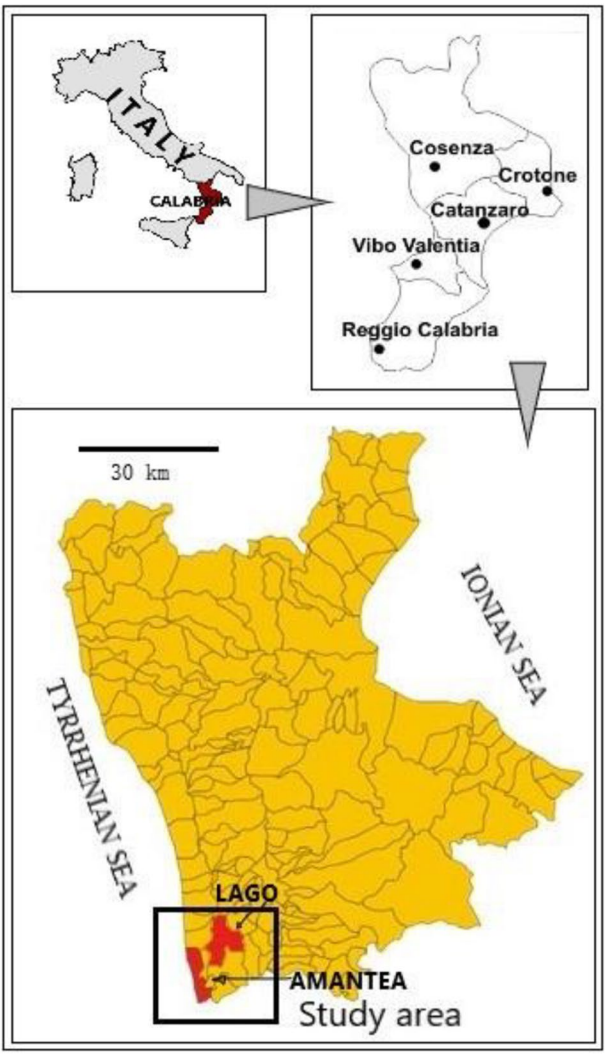

Fig. 1 Location of the study area (from Antronico et al. 2020)

Amantea (13,770 inhabitants, 2021 Italian Census) develops along the Tyrrhenian Coast, and it is characterized by a hilly morphology that expands between the narrow coastal plain, and an altitude of about 430 m above sea level is often affected by geo-hydrological phenomena that threaten the population and cause damage to buildings and infrastructures. In particular, in January 2021, after heavy rainfall events, the historic center of Amantea was affected by a rockfall whose blocks reached some private buildings and a municipal road. Moreover, the narrow coastal plain, as the whole Tyrrhenian Coast side, is frequently hit by severe coastal erosion phenomena by the sea. The inhabitants of Lago are 2318 (2021 Italian Census); its territory is mainly characterized by a mountain morphology and by a high frequency of both superficial and deep mass movements of different types. Evidence of landslide activity effects can be found in the cracking of buildings, distortion of roads, and bending of old trees (Borrelli and Muto 2017).

In consideration of this exposure to geo-hydrological events, and considering that climate change might cause an increase in the frequency and intensity of damaging events, it is paramount to evaluate the social community resilience of the population living in these two municipalities.

2.2 Data collection

The analyzed data in this study are from a database performed in the framework of a Research Project focused on the risk perception of natural hazards and social vulnerability of population living in coastal areas subject to climate change in Malta and Calabria (Southern Italy) through a survey conducted by means of a questionnaire. These two Mediterranean regions, despite showing different physical and climatic contexts, display commonalities in terms of exposure to climate risk. Regarding Calabria, the study area considered in the project were the municipalities of Amantea and Lago (Antronico et al. 2020). Data collection was realized in the period October–November 2019, using a standardized questionnaire administered to the population of the two municipalities, collecting a total of 300 units (200 for Amantea and 100 for Lago). The administration was realized employing a face-to-face interview and using the CAPI methodology (computer-assisted personal interview) (Collins and Sykes 1998; Forster 1999) and a per quote non-parametric approach, with a stratification based on gender and age. The questionnaire has 33 questions divided into three sections (socio-demographic information, social perception of climate changes, social resilience to extreme natural events) with different possibilities of answers (yes/no, multiple-choice, scale of intensity, or Likert scale).

Appendix A shows the sections, the queries, and the response format of the standardized questionnaire implemented for the project and administered to the population of the two municipalities.

The sample is composed as follows, considering a unique sample including the two study areas: 48% male and 52% female, 31% people aged 18–39, 34% people aged 40–59, and 35% people aged 60 and over. Sixty-four percent had a secondary education level, and 32% had a university-level education. The respondents without occupation were 11%, while most of the employed were office workers (40%), followed by entrepreneurs and freelancers (13%). Twenty-two percent were retired workers, 7% were students, and 7% were homemakers.

For this study, only 19 questions considered more representative were chosen from the questionnaire implemented for the project, as precisely indicated with an asterisk in Appendix A.

2.3 Methodology

The variables were represented by each single-choice question and by each portion of a multiple-choice question of the questionnaire submitted to the sample population, and the data were stored with a specific software. Then, descriptive statistics were calculated for every variable, splitting the database into two groups, each of them representative of the two study areas. Results from descriptive statistics were then utilized for the subsequent multi-criteria analysis. The multi-criteria analysis was performed by using the method/software Promethee (Preference Ranking Organization METHod for Enrichment of Evaluations) (Brans and Mareschal, 2002, 2005), which uses a hierarchy of

criteria based on preference degrees and allows for a classification of the studied area in terms of the investigated concept (the social resilience/vulnerability).

We decided to choose this method, among the other possible about MCDA analysis, because it is easy to use, and provide a visual aid (the so-called Gaia Plane), both important points of strength for final non-expert users (Abdullah et al. 2021). In addition, previous studies demonstrated that the method can be easily applied to different areas, providing a good robustness (see, e.g., Carone et al. 2019).

The principal steps of this analysis can be summarized as follows: (a) individuation and weighing of macro-indicators, or dimensions characterizing the social resilience; (b) individuation and weighing of sub-indicators characterizing macro-indicators; (c) choice of the preference function, based on the available data; (d) calculation of the preference flows and definition of the final ranking, expressed by a value Φ (Phi) of the net flow (as better specified below); (e) sensitivity analysis for measuring the robustness of the final ranking; and (f) graphical representation of the results with the GAIA Plane module provided by the Promethee Software.

For this specific work, the sensitivity analysis is not employable because of the presence of only two study areas. Meanwhile, such a step has demonstrated to be very reliable in order to have information about the obtained ranking (see, e.g., Carone et al. 2018; Carone et al. 2019).

The Promethee method is based on a pair-wise preference that calculates the following:

1. A positive flow, which shows the preference of an alternative, i.e., alternative A, over the other alternatives.
2. A negative flow, which represents how all the other alternatives are preferred to the alternative A, on average.
3. A net flow, obtained by subtracting the negative flows from the positive ones; the net flow is the one used for the final ranking of the studied areas.

The method allows for the choice of different preference functions for the net flow calculation, i.e., the chosen preference function individuates the preferred alternative through a comparison based on specific criteria (Brans and Mareschal, 2002, 2005). For the present work, we decide to follow the suggestion of the authors of the method to use the level function (Ishizaka and Nemery 2013), considered the best choice for mainly qualitative data, as the ones collected with the questionnaire.

Macro-indicators and sub-indicators—the variables represented by the question of the questionnaire—were chosen taking into account the more influential aspects for social resilience, based on the most important literature in the field. Also risk perception was considered, since it is a fundamental component of social resilience but also of vulnerability (Brody 2008). For the approach, we applied the method of the empirical conceptualization of a complex concept (Arlotti et al. 2008; Corbetta 2015b) and a hierarchical weighting of both macro-indicators and sub-indicators. In Fig. 2, a general scheme of the whole process is shown.

Table 1 reported the five chosen macro-indicators, the rationale used as a basis for their choice, and their weight, in percentage, assigned following the indications of an international panel of ten experts, mediating their judgment (Carone et al. 2019). For each of the five macro-indicators, some of the literature references that have contributed to the theoretical basis for their identification are also reported.

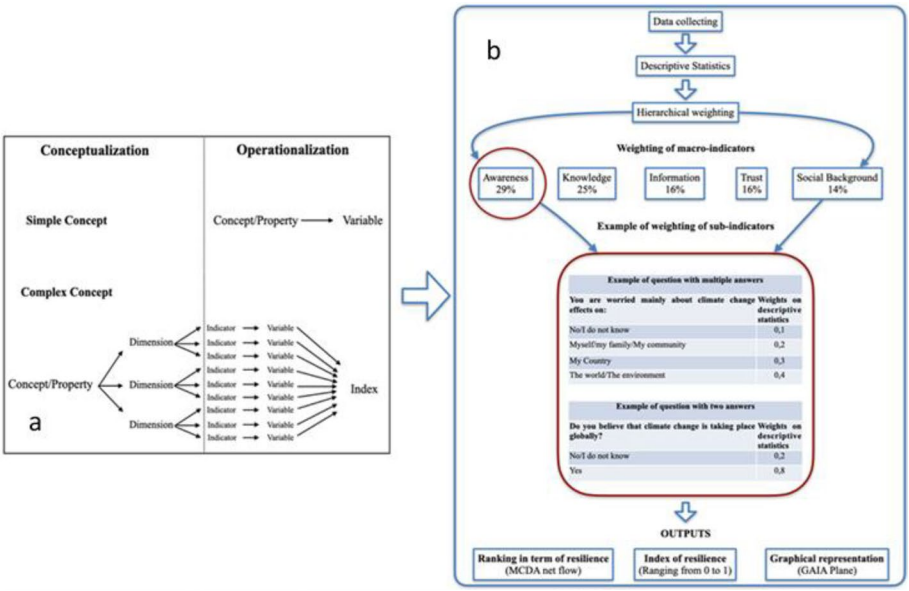

Fig. 2 From the empirical conceptualization of a complex concept (**a**) (modified from Corbetta 2015b) to the scheme of the provided approach in this paper (**b**)

The weight of each sub-indicator was assigned based on the importance of each answer to the main concept (the resilience); the lower the weight, the lower the resilience (and vice versa). Also the sum of all the weights of a single sub-indicator is equal to 1.

The weight for each sub-indicator is assigned as indicated in Tables 2, 3, 4, 5, and 6, where for each macro-indicator is described the characterizing sub-indicators and their possible answers.

For the construction of the Index of Resilience, we started from the assumption that it would be user-friendly in order to be really effective. For the approach, we used a summative mode combined with a multiplicative mode. For each macro-indicator, we obtained a final value by adding the ratios between the sum of the values of the answers to each sub-indicator and the possible maximum values for them, all weighted as reported in Tables 2, 3, 4, 5, and 6. These ratios, characterizing the single macro-indicator, were multiplied for the weight chosen by the panel of ten international experts for the same macro-indicator (Table 1). The five final values were then added together, giving an index that ranges from 0 (lowest resilience) to 1 (highest resilience). The approach can be summarized in Formula 1:

$$I_{Re} = \sum_{k=1}^{5} \frac{M_k}{M_{maxk}} W_k \tag{1}$$

where I_{Re} = Index of Resilience; M_{k} = value of each macro-indicator, obtained by adding the values of each sub-indicator (the answer to the questions); M_{maxk} = maximum possible value for the macro-indicator; and W_{k} = weight of the macro-indicator.

Such an approach gives, then, the possibility to have two major results:

Table 1 The five chosen macro-indicators (awareness, knowledge, information, trust, and social background) and their weight. Some of the reference literature for each macro-indicator are shown in brackets

Macro-indicators	Rationale for the choice of each specific macro-indicator	Weight of the macro-indicator
Macro-indicator 1—Awareness (e.g., Miceli et al. 2008; Raaijmakers et al. 2008; Papagiannaki et al. 2019)	Many authors underline the strict link between the awareness of a risk and the inclination to adopt measures to prepare for it. Such an inclination to prepare to a negative event can be considered, then, a crucial aspect for increasing the resilience of a population	29%
Macro-indicator 2—Knowledge (e.g., Lechowska 2018; McEwen et al. 2018; Carone et al. 2019; Kammerbauer and Minnery 2019)	Knowledge of the effects of a natural disaster strongly influences the behaviors implemented during the event. This influence is so strong that a previous experience of a natural disaster is considered by many authors to be one of the factors that most influence the social resilience of a community	25%
Macro-indicator 3—Information (e.g., Longstaff and Yang (2008); Marincioni 2007; Appleby-Arnold et al. 2018; Carone 2018)	Many authors underline as the way how information is provided to the populations can heavily influence the community social resilience to natural disasters. In last decades, this becomes even more important, given the possibility to have a more widespread information, thanks to better technologies	16%
Macro-indicator 4—Trust (e.g., Terpstra et al 2009; Waugh and Streib 2006; Wachinger et al. 2013)	The role of trust in institutions in influencing the community social resilience as well as risk perception is well acknowledged in literature. Indeed, it influences the propensity of a population both to implement mitigation measures and to believe in specific information about natural hazards	16%
Macro-indicator 5—Social background (e.g., Lechowska 2018; He et al. 2021; MA et al. 2022)	In the last decades, many study focusing on resilience to climate change payed major attention to social background as an aspect that influences resilience and also is influenced by negative effects of natural disasters. Such an aspect is then crucial for studies with the aim to evaluate the social community resilience	14%

Table 2 Weight of the sub-indicators related to Macro-indicator 1—Awareness

Macro-indicator 1—Awareness			
Question of questionnaire	Answer	Weight	Weight justification
Q.16 Do you believe that climate change is taking place globally?	- No/I do not know - Yes	0.2 0.8	The highest weight underlines the confidence that climate changes are already taking place, considered a *sine-qua-non* basis for the implementation of correct behaviors
Q.17 You are worried mainly about climate change effects on:	- No/I do not know - Myself/my family/my community - My country - The world/the environment	0.1 0.2 0.3 0.4	The highest rank corresponds to the awareness that climate changes are a problem at a global level, for the whole of humankind, and not only for a single citizen
Q.24 Please indicate at least two actions that you (or your family) daily do to cope with climate change:	- I do nothing - I talk to friends/family/local officers - Waste sorting/tree planting/gardening - Transport/thermal insulation/plastic reduction/eating	0.1 0.2 0.3 0.4	The best value is for the behavior expressed spontaneously by the single citizen and not because of legal obligation (e.g., waste sorting). This spontaneity is a real difference in the daily lifestyle of citizens
Q.27 When do you think the effects of climate change will be evident both globally and locally?	- I do not know/I do not think there are effects - After the next 50 years - Within the next 50 years - They are already acting	0.1 0.2 0.3 0.4	The best value rewards the awareness that climate change is a phenomenon already acting

Table 3 Weight of the sub-indicators related to Macro-indicator 2—Knowledge

Macro-indicator 2—Knowledge			
Question	Answer	Weight	Weight justification
Q.18 In your opinion, which of the global phenomena listed below are associated with climate change?	- I do not know	0.1	The best value was assigned to the knowledge that allows for linking climate changes and other phenomena heavily influencing the planet's life, not only the single individual
	- Immigration/conflicts	0.2	
	- Melting glaciers/temperature/ drought	0.3	
	- Greenhouse effect/extreme phenomena/ extinctions	0.4	
Q.19 In your opinion, which of the local phenomena listed below are associated with climate change?	- I do not know	0.1	The best value was assigned to the knowledge that allows for linking climate changes and other phenomena heavily influencing the community's life, not only the single individual
	- Immigration/illnesses	0.2	
	- Damages to agriculture/ economic damages	0.3	
	- Fires/drought/extreme phenomena	0.4	
Q.21 Do you think that floods/storms/landslides/ coastal erosion/drought/heat waves/frost wave phenomena are linked to climate change?	- No/I do not know	0.2	The best value strongly highlights the knowledge that allows for linking the mentioned extreme phenomenon and climate change
	- Yes	0.8	

Table 4 Weight of the sub-indicators related to Macro-indicator 3—Information

Macro-indicator 3—Information			
Question	Answer	Weight	Weight justification
Q.20.1 Climate changes are linked to the economic policies of industrialized countries/to the daily lifestyle of citizens	- Completely disagree	0.1	For Likert scale, we chose to unify in the highest level the elements in agreement with the statement, so as to better underline the transition from the uncertain level
	- Agree	0.2	
	- Uncertain	0.3	
	- Agree/completely agree	0.4	
Q.20.3 Climate changes are linked to the normal evolution of the planet Earth	- Agree	0.1	For Likert scale, we chose to unify in the highest level the elements in agreement with the statement, so as to better underline the transition from the uncertain level
	- Completely agree	0.2	
	- Uncertain	0.3	
	- Disagree/completely disagree	0.4	
Q.23 Do you think to be informed enough about climate change?	- No/I do not know	0.2	The positive answer receives the best value, notwithstanding this is a question to be carefully valued, since it is about personal perception
	- Yes	0.8	
Q.25 What are your main sources of information about climate change?	- Family/friends	0.1	We chose to assign the best value to the institutional sources of information because they are the first ones that cope with climate change effects and also as an indirect value of trust in institutions
	- Television/newspapers/internet/social media	0.2	
	- University/school	0.3	
	- Civil protection/institutional administrations	0.4	

Table 5 Weight of the sub-indicators related to Macro-indicator 4—Trust

Macro-indicator 4—Trust			
Question	Answer	Weight	Weight justification
Q.20.2 How much do you agree with the statement "climate changes are a journalistic hype"?	- Agree	0.1	For Likert scale, we chose to unify in the highest level the elements that disagree with the statement, so as to better underline the transition from the uncertain level
	- Completely agree	0.2	
	- Uncertain	0.3	
	- Disagree/completely disagree	0.4	
Q.22 Do you believe that there are sufficient national and international political actions for reducing climate change?	- No/I do not know	0.2	A positive answer, that received the best value, is possible only if trust in institutions is present
	- Yes	0.8	
Q.28 May you tell me which of the following statements you agree with?	- I am not worried about climate changes	0.1	We assigned the best value to the highest trust because it is linked to more proactive behaviors in the search of possible solutions
	- Institutions do not enough/I am worried about climate changes	0.2	
	- I am confident that institutions will decrease climate changes	0.3	
	- I am sure that institutions are implementing correct strategies	0.4	
Q.29 In case of extreme events, how do you think will you behave?	- I do not know/I would not know what to do	0.1	The best value was assigned to trust in authorities and in personal abilities. This last aspect should be carefully valued since it is a personal perception
	- I would trust God	0.2	
	- I would look for information	0.3	
	- I would know what to do/I would wait for the authorities	0.4	
Q.31 In case of extreme events will you trust the authorities?	- No/I do not know	0.2	We chose to assign the best value to the positive answer since trust in authorities leads to more careful and proactive behaviors for single citizens
	- Yes	0.8	

Table 6 Weight of the sub-indicators related to Macro-indicator 5—Social background

Macro-indicator 5—Social background			
Question	Answer	Weight	Weight justification
Q.7 Are there members over 65 years in your family?	- Yes	0.2	We valued with the highest level the negative answer since the presence of older people is associated with a higher vulnerability/lower resilience
	- No	0.8	
Q.8 In your family, are there non-self-sufficient people?	- Yes	0.2	We valued with the highest level the negative answer since the presence of non-self-sufficient people is associated with a higher vulnerability/lower resilience
	- No	0.8	
Q.9 Where do you live?	- Rural context	0.2	The best value is assigned to the urban context for the facilities of this location in terms of resilience
	- Urban context	0.8	
Q.12 What is your job?	- Unemployed/student	0.1	The best value is assigned to a higher degree of economic stability even if the level immediately below is associated to higher resourcefulness and work independence
	- Housewife/retired	0.2	
	-Entrepreneur/freelance	0.3	
	- Employed	0.4	
Q.14 What is your educational level?	- None/primary school	0.1	We choose to associate to a higher school level a higher degree of resilience/lower degree of vulnerability
	- Middle school	0.2	
	- Secondary school	0.3	
	- Graduation and above	0.4	

- On one hand, a robust ranking when studying different areas, in terms of resilience, given by the net flow obtained with the MCDA analysis (Brans and Mareschal 2005).
- On the other hand, an Index of Resilience, which can produce levels of resilience, since its structure allows for a computation from 0 to 1. This computation leads to the possibility that the values of the index can be thresholded in five levels of resilience (0–0.2 = very low, 0.2–0.4 = low, 0.4–0.6 = medium, 0.6–0.8 = high, 0.8–1 = very high).

In addition, the Promethee method provides also a graphical representation of the results, the Gaia Plane, in which the same statistic can be seen in a very user-friendly manner, without further calculations. For a thorough description of all the statistics of the Promethee method, which is beyond the purposes of the present article, see Brans and Mareschal (2005) and Nemery et al. (2012).

3 Results and discussions

The multi-criteria analysis allowed for the construction of a concise index for the evaluation of resilience, able to provide information also on vulnerability, assuming this last one as an inverse aspect of resilience. The results of such index underline that in terms of a general evaluation, both the studied areas show the same value (0.8 for Amantea as well as for Lago), suggesting a good resilience, and indeed a low vulnerability. But, both resilience and vulnerability are multi-dimensional concepts, and then the approach provides also a classification of the studied areas in terms of social resilience individuating, for each of them, the most influential macro-indicators. Each macro-indicator is characterized by (i) multi-dimensionality, which takes into account not only demographic aspects but also risk perception, information, knowledge, and trust in institutions and authority, already stressed as very important aspects by Dwyer et al. (2004); (ii) theoretical and internal consistency and robustness as well as suitability and replicability, since they are the characteristics of a good indicator, as highlighted by Spielman et al. (2020).

The pair-wise preferences calculated through the Promethee method allow for a concise value for the final net flow, which for Amantea suggest a better social resilience ($\Phi = 0.35$) compared to Lago ($\Phi = 0.22$). This is an important further information, in addition to the one expressed by the general index of social resilience, because this underlines some differences between the two study areas.

The methodology, though, gives the additional possibility of individuating also the dimensions—macro-indicators—that better contribute to the resilience of studied communities.

This additional analysis shows for Amantea higher importance of knowledge, awareness, and social background macro-indicators. Conversely, Lago shows a higher influence given by trust and information, whereas the others are more critical (Fig. 3). This result is particularly interesting because it gives a good idea of the many facets linked to the concept of resilience.

With a different graphical representation provided by the software Promethee, the Gaia-Plane, we can appreciate other additional information about these facets represented by the differences on the influencing behavior of macro-indicators on social resilience (Fig. 4).

The Gaia-Plane is a virtual bi-dimensional space where the axes represent the ideal social resilience (the red axis) and the macro-indicators that characterize it (the green axes).

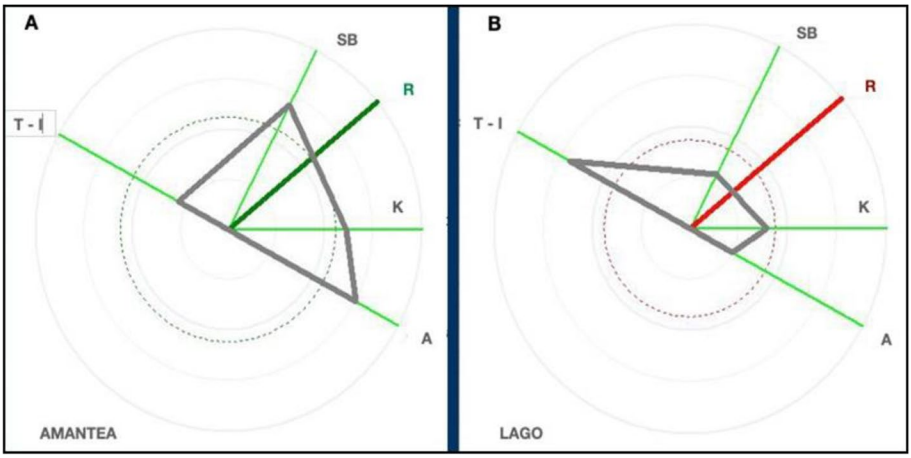

Fig. 3 Influence of the macro-indicators employed for the evaluation of social resilience of the study areas (Amantea (**A**) and Lago (**B**)). R, resilience axis (in dark green for Amantea and red for Lago). Macro-indicators = trust (T), information (I), social background (SB), knowledge (K), awareness (A). The portion highlighted with the gray line graphically represents the area of the influence of macro-indicators over the social resilience of the two areas

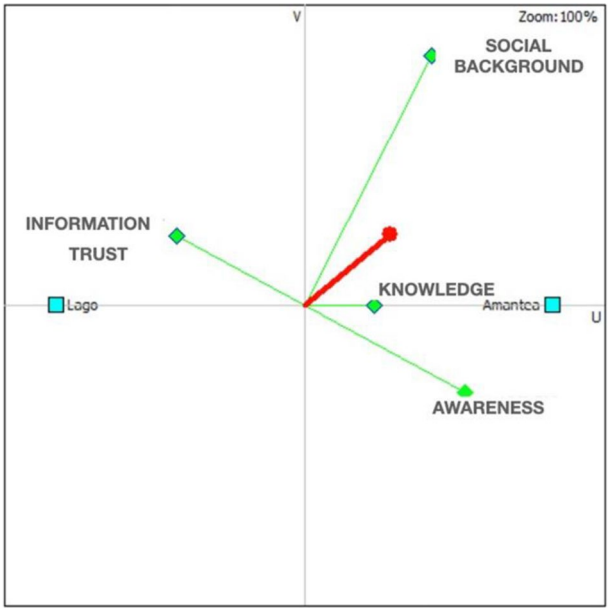

Fig. 4 Gaia-Plane of social resilience of the two study areas. In red is the ideal social resilience, which integrates in the best way all the macro-indicators utilized for the analysis (green axes). The blue squares represent the study area (Amantea and Lago)

The location of macro-indicator axes into the quadrants of the scheme, their orientation compared to social resilience's axis, and their distance from it provide information on the influence of macro-indicators on social resilience. In particular, macro-indicators expressing similar preferences are similarly oriented. Following the same concept, also the location of study areas into the quadrants gives information about what

macro-indicators are more influencing for them and also about how similar these areas are; dissimilar areas are located far from each other (Brans and Mareschal 2005; Visual PROMETHEE 1.4 Manual 2013).

This kind of graphical information can be very useful to better understand the role of macro-indicators. Indeed the index of social resilience, which aggregates all the data, show the same value for the two studied areas; on the contrary, observing the Gaia Plane, it is very clear that the two study areas occupy very different portions in the quadrants and are closer to different macro-indicators. Specifically, Amantea is closer to the macro-indicators that seem to be more influential for the ideal social resilience, such as knowledge and awareness; this justify the first position of Amantea in the final ranking. Lago, which occupies the second position, is closer to macro-indicators that seem less influential for the ideal social resilience (information and trust).

This additional information compared to the one obtained through the index allows for a better understanding of the aspects that play a major role in maintaining an acceptable social resilience level for specific communities. Actually, the index of social resilience provides for both municipalities a good level of social resilience and so a low level of vulnerability, since it ranges from 0 to 1 and shows a value of 0.8. The Gaia plane, in addition, communicates that the aspects that allow for this result are different; hence, the two populations cope with social resilience in different ways that the proposed method was able to point out.

Indeed, Amantea that is a municipality with a high presence of tourism in summer has a good internet network for providing information regarding its own territory: this easily explains the higher level of knowledge. On the other hand, Amantea was twice put under control of the Italian government for suspicion in administrative matters which is a very good reason for citizens not to have trust in local institutions. Conversely, Lago has a Mayor who received a second mandate because of his steadfast activity for the good of the community: this improved the citizens' trust in institutions. Both the described situations seem to be correctly enlightened by the proposed approach. The results, then, provide useful information about what kind of macro-indicator can be considered more critical and for this reason needing more attention in terms of a future implementation of measurement of management.

The approach, thus, is based on the consideration that vulnerability and resilience can be regarded as two opposite aspects of the same problem, in agreement with numerous other researchers in this field (Ran et al 2020 and references therein). Moreover, given that the vulnerability can also be considered a measure of resistance of a society to a hazard (Cutter et al. 2003), the two concepts are further and heavily linked. The applied methodology starts from the perspective that vulnerability and resilience are influenced by other factors in addition to the largely used in literature, mainly regarding demography, poverty, and infrastructures (e.g., Cutter et al. 2003; Armas 2008; deLoyola Hummell et al. 2016; Fatemi et al. 2019). In addition, a mandatory role is paid by the risk perception (Brody 2008). For this reason, the individuated macro-indicators are able to provide information on dimensions linked to the following aspects of the studied communities (e.g., Norris et al. 2008; Gierlach et al. 2010; Salvati et al. 2014; Crescimbene et al. 2015; Farinella et al. 2017; Antronico et al. 2017; Lechowska 2018; Antronico et al. 2019; Carone 2018; Papagiannaki et al. 2019): (i) awareness of the problem, (ii) knowledge of the link between climatic phenomena acting in this century and the problem, (iii) trust in institutions, (iv) information, and (v) social characteristics. A further point of strength of the methodology is that these macro-indicators are also characterized by the facility of retrieval of information. In fact, data collection phase was

performed by delivering to population a questionnaire, a common tool for social study, easy to employ (Corbetta 2015a).

4 Conclusion

Climate change not only affects the economy and the environment, but also the health and well-being of citizens. Therefore, improving adaptability, strengthening resilience, and reducing vulnerability to climate change and its impacts on ecosystems and society have now become a global challenge. The present study shows the results of a survey on assessment of social resilience to climate change using a questionnaire-based data collection in a specific area of Calabria (Southern Italy) affected by geo-hydrological events and coastal erosion.

The concept of social resilience is multi-dimensional, and for this reason, we individuated macro-indicators describing it, which consider not only aspects linked to demography, poverty, and urban structure, frequently used in literature (Frigerio et al. 2018; Huynh et al. 2018; Christian et al. 2021; Kumar and Kumar Battacharjya 2020), but also further social information, such as risk perception, awareness, knowledge, and information.

These last social macro-indicators, even if considered of crucial importance to evaluate social resilience, have been considered, in the past, difficult to quantify (Dwyer et al. 2004), and then often neglected in previous studies. We overcome this specific aspect combining the use of a questionnaire, a very easy-to-use tool for social studies, with a MCDA analysis.

Given the fact that also the macro-indicators are multi-dimensional, in the approach, they are characterized by sub-indicators with a hierarchical weighted structure.

Such a structure proved to be very effective, since it was able to point out different facets of the same concept, the different influence of the macro-indicators, that would be hidden if only a single index was used.

Indeed, the two study areas show different contribution of the analyzed macro-indicators to the ideal resilience even if both reach the same level of the Index of Resilience. This result confirms the necessity to fit the implementation of management measures on local characteristics when the territory is so various as the Italian one. This is a particularly important aspect since the major difficulty of the studies about social resilience lies in the complexity of the nuances of the studied concept. Trying to highlight such nuances is difficult and often represents a threat for the impartiality of the study (Fekete 2009). Indeed, the methods typically used for the data collection of social study—like the one we used in the present work—can be affected by an excessive subjectivity, even if they are really effective in the collecting of information.

The hierarchical weighted approach proposed in this paper certainly does not eliminate completely the subjectivity deriving from a semi-qualitative data collection method, but the use of a mediating weighting of macro-indicators and sub-indicators taking into account the judgment of several experts in the field strongly reduces such subjectivity. Given the efficacy of the method on providing a good amount of data using an easy way of collecting them such a weighted hierarchical structure may represent a good compromise.

In addition, the hierarchical structure given to macro- and sub-indicators gives the possibility to add other elements, when needed because of specific characteristics of different study areas, without changing its interpretability.

This specific aspect is very important, since resilience to risk deriving from climate changes can be very different depending on the geographical location of the studied area. Indeed, in Italy areas not so far from each other can show very different characteristics, since the Italian territory is characterized by an extraordinary amount of diverse landscapes, which differently influence the macro- and sub-indicators used for the hierarchical structure of the study, as the case showed in the present paper. For this reason, a tool able to be easily implemented with further sub-indicators characterizing the macro-indicators, on the basis of the community differences, can be particularly helpful and "resilient" itself.

Then, the proposed approach can be considered a useful compromise because, starting from an easy data collection, it allows for (i) expressing and investigating the multi-dimensionality of complex concepts as social resilience/vulnerability, (ii) expressing the social resilience levels of studied areas by mean of an index both concise and easy to interpret, (iii) individuating the most influential dimensions among the analyzed ones, (iv) decreasing the subjectivity linked to the data collection by means of a system of mediated weights by a panel of experts on the field, and (v) allowing for a sensitivity analysis, in order to carry out information about the robustness of the results, when an adequate number of study areas is available. Finally, the approach provides also useful information on vulnerability of the studied population, assuming vulnerability and resilience to face of a same coin.

The findings of this study can be considered very useful for the management of vulnerable areas to climate change, especially in those areas exposed to high-impact events such as the case study shown. In fact, the information about the resilience of community exposed to risks may help decision-makers in adopting and implementing preventive measures to mitigate negative consequences of climate change.

Appendix A

Questionnaire implemented for the Project funded under the Agreement on Scientific Cooperation between CNR and the University of Malta (UoM) and administered to the population of the Lago and Amantea Municipalities (Antronico et al. 2020). The asterisk indicated the questions chosen and analised in this article

QUESTIONS	RESPONSE FORMAT
SECTION 1 - SOCIO-DEMOGRAPHIC CHARACTERISTICS	
Q.1 Place of residence	Open-ended question
Q.2 Gender	• Male • Female • I'd prefer not to say
Q.3 Age class	• 18 - 39 • 40 - 60 • > 60
Q.4 Nationality	Open-ended question
Q.5 If you are foreign, do you have a problem to understand the language where you live in?	• Yes/No
Q.6 How many members are there in your family?	• 1 • 2 - 3 • 4 - 5 • ≥ 6

QUESTIONS	RESPONSE FORMAT
***Q.7** How many of your family are of the following age group?	• 0 ≤ 14 • 0 ≥ 65
***Q.8** Are there any members of your family who are not functionally independent?	• Yes/No
***Q.9** Do you live in	• Urban area • Rural area
Q.10 When was the dwelling in which you live constructed?	• Before the 1970's • After the 1970's • I don't know
Q.11 What type of dwelling do you live in?	• Privately owned luxury / high quality property • Rented luxury / high quality property • Privately owned standard quality property • Rented standard quality property • Privately owned low-quality property • Rented low-quality property • I don't know
***Q.12** Occupation	• Unemployed • Student • Pensioner • Housewife/husband • Dependent • Business owner / freelance
Q.13 How long does it take you to reach your place of work/study?	• 15 minutes on foot • 15 minutes by car or public transport • Between 15 to 60 minutes on foot • Between 15 to 60 minutes by car or public transport • More than 60 minutes on foot • More than 60 minutes by car or public transport • I don't know
***Q.14** Education	• None • Primary school level • Secondary school level • Post-secondary school level • Tertiary level
Q.15 According to you, which of the following social problems are present in the community you live in? [maximum 2 answers]	• Drugs • Alcohol • Gambling • Unemployment • Problems related to citizen security • Depopulation and youth emigration • I don't know
SECTION 2 - SOCIAL PERCEPTION OF CLIMATE CHANGE	
***Q.16** Do you believe that climate change is taking place globally	• Yes/No/ I don't know
***Q.17** Overall, are you preoccupied by the impacts of Climate Change on: [maximum 2 answers]	• Yourself, your family, the community in which you live? • Your country? • The whole world? • Nature and the environment? • Nobody? • I don't know

QUESTIONS	RESPONSE FORMAT
***Q.18** According to you, which "global" phenomenal listed below, are associated with Climate Change? [maximum 3 answers]	• Increasing temperatures • Melting of ice and sea level rise • Ozone hole and Greenhouse effect • Increase in the frequency of extreme events such as hurricanes, tropical storms, floods, heat and coldwaves • Loss of biodiversity and loss of animal and plant species • Growth in immigration and conflicts • I don't know
***Q.19** According to you, which "local" phenomenal listed below, are associated with Climate Change? [maximum, 3 answers]	• Growth of fires • Decrease in agricultural and fisheries production • Shortage of water resources • Diffusion of diseases • Increase of immigration • Economic losses and negative impacts on local tourism • Increase in storm showers with impacts on people • I don't know
***Q.20** How true do you consider the statements on Climate Change (1 low, 5 high) 20.1 Climate Change is related to the economic policies of largely industrialized countries 20.2 Climate change is a journalistic mount 20.3 Climate changes are tied to natural planetary evolution 20.4 Climate changes are also tied to daily lifestyles	Five-point scale + I don't know
***Q.21** Do you believe that the following extreme phenomena are linked to Climate Change? Landslides Floods Earthquakes Coastal erosion Volcanic eruptions Hurricanes Tsunamis Drought and heatwaves	• Yes/No/ I don't know
***Q.22** Do you believe that national and international political actions are sufficient for reducing Climate Change?	• Yes/No/ I don't know
***Q.23** Do you feel sufficiently informed on Climate Change?	• Yes/No/ I don't know
***Q.24** Indicate at least two actions taken by yourself (or your family) or which can be taken to address Climate Change [maximum 2 answers]	• Use of heating systems based on the use of renewable resources • I have improved the insulation of my house • I plant trees and care for the plants in my garden • I often use alternative transport options to the car • I often discuss with friends, relatives and local politicians on how to reduce Global warming • I always carefully carry out waste separation • I daily seek to limit the use of plastic material • In my daily food intake, I have reduced or excluded the consumption of beef • I do not take any actions to reduce Climate Change

QUESTIONS	RESPONSE FORMAT
***Q.25** Which are your main sources of information on Climate Change? [maximum, 3 answers]	• Newspapers, books, reviews • Television • Relatives and friends • Internet and social networks • University • School • Regional/Provincial/Communal •Civil Protection
Q.26 In your opinion, which among those listed below, is the main cause of Climate Change?	• Deforestation • Livestock farming • None of these • I don't know
***Q.27** In your opinion, will the effects of Climate Change start to manifest themselves both globally and locally?	• We are already seeing the effects • In the next 50 years • After the next 50 years • I exclude that in the future we will see effects • I don't know
***Q.28** Can you tell me, which of these statements you personally agree with?	• I am frustrated because not enough is being done about Climate Change • I am sure that the correct strategies are being implemented to slow down Climate Change • I am confident that we will succeed to slow down Climate Change • I am afraid of the possible effects of Climate Change • I am not very concerned with Climate Change • I do not know how to respond
SECTION 3: PSYCHOLOGICAL RESILIENCE IN THE FACE OF AN EXTREME NATURAL EVENT	
***Q. 29** If an extreme natural event should occur, how would you think to behave?	• I know what I should do • I do not know what I should do • I try to obtain emergency information via T.V., social network, internet, radio, neighbors, experts • I wait the intervention of the authorities • I trust in God • I do not know how to reply
Q.30 If an extreme natural event should occur, what could your reactions be? [maximum 2 answers]	• I rush to find an escape route • I help first my family and others who are in difficulty • I panic • I do not panic • I remain where I am • I do not care • I do not know how to reply
***Q.31** If an extreme natural event should occur, would you have confidence in the capacity for intervention and the preparation of local government authorities?	• Yes/No/ I don't know

QUESTIONS	RESPONSE FORMAT
Q.32 Listed below is a series of events. How do you think you are personally exposed to each of these events? (1 low, 5 high) Landslides Floods Earthquakes Coastal erosion Volcanic eruption Hurricane Tsunami Heatwave Coldwave	Five-point scale + I don't know
Q.33 Mark with an X the damage you fear most, for every extreme event that could occur in your territory (a maximum of two types of damage can be indicated) Landslides Floods Earthquakes Coastal erosion Volcanic eruption Hurricane Tsunami Heatwave Coldwave	• Personal physical damage to you or to someone of your family • Property damage and / or buildings • Damage / unusability of the workspace • Personal psychological problems • I don't know

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Data availability All data generated or analyzed during this study are included in this published article (and its supplementary information files).

Declarations

The submitted work is original and has not been published elsewhere in any form or language.
The authors have the consensus of the respondents for the use of questionnaires.
The authors did not receive support from any organization for the submitted work.
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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