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Risk Mitigation, Vulnerability Management and Resilience under Disasters

Edited by
Kalliopi Sapountzaki

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Editor

Kalliopi Sapountzaki

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Editor
Kalliopi Sapountzaki
Harokopio University of Athens
Greece

Editorial Office
MDPI
St. Alban-Anlage 66
4052 Basel, Switzerland

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Cover image courtesy of Kalliopi Sapountzaki.

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About the Editor

Kalliopi Sapountzaki, Professor (Spatial Planning and Protection from Natural Disasters), Department of Geography, Harokopio University of Athens. Ph.D. in Risk Management, Spatial Planning, National Technical University of Athens 1990, MA in Urban Design, University of Manchester 1981, Diploma in Architecture, NTUA 1980. She is responsible for under- and post-graduate University Courses on Spatial and Development Planning and Risk and Disaster Management. She has been the scientific leader of the Greek part of the EC research projects focusing on Vulnerability to Hazards, Risk-Informed Spatial Planning and Risk Governance. She has participated in national and EC project consortiums dealing with Territorial Governance, Sustainable Development, Planning for Sustainable Tourism and Marine Spatial Planning. She has published her work in international books and scientific journals focusing on Risk and Disaster Management, Risk and Territorial Governance, Spatial Planning, Sustainable Development. She is member of the Board of the Society for Risk Analysis-Europe. She has held lectures at several universities across Europe.

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Editorial

Risk Mitigation, Vulnerability Management, and Resilience under Disasters

Department of Geography, Harokopio University of Athens, 17676 Kallithea, Greece; sapountz@hua.gr

The present Special Issue is devoted to vulnerability management and resilience-building as cornerstones of disaster risk mitigation.

For decades, experts and management authorities have worked strenuously for disaster risk mitigation at all levels, from global to local, but the results of the respective efforts have been poor. Disasters and disaster losses continue to increase in number, along with the affected populations, the extent of the affected areas, and the loss value [1]. Over the last 20 years, more than 7000 natural disaster events have been recorded worldwide, claiming around 1.23 million lives, affecting more than 4 billion people, and causing economic losses of approximately USD 2.97 trillion [2]. In addition, it has become more difficult for the most vulnerable victims to recover after disasters. Part of the explanation for this inconsistency between efforts and results may be due to the increase in the number and intensity of extreme meteorological and climatic events associated with CC. However, most of the reasons for the inconsistency are found in the lack of ability or willingness of all those involved in disaster risk mitigation to proactively achieve vulnerability reduction and/or resilience-building using strategies and measures, which probably imply sacrifices in development gains. The present Special Issue deals with the factors underlying this incompetence and ways to redress it.

Poor attention to vulnerability reduction and missing policies for resilience-building are due to several reasons. One reason comes from the over-confidence and emphasis put by managers on environmental engineering works as the most effective means to counteract hazards [3]. This option disregards not only the unpredictability of certain hazards and the elusive sense of safety created by technical works but also the decisive role of spatial (and other forms of) development in several aspects of exposure and vulnerability (human, social, economic, institutional, cultural, territorial, etc.). Indeed several losses and their persistence are due to pre-existing exposure and vulnerability, with territorial and institutional vulnerability being the most neglected, despite their primary importance.

A second reason for the lack of vulnerability reduction and missing policies is risk-blind development plans. Development has been associated with positive economic expectations, income increases, and improved habitation opportunities [4]. Therefore, spontaneous spatial development and statutory planning follow social aspirations that may even be hazardous to develop privileged but sensitive and/or hazardous environments (e.g., coastal zones, riverbanks, peri-urban forest land, etc.). These dynamics result in extensive landscapes at risk of flood, forest fire, and other disasters and a widespread culture opposing vulnerability/exposure reduction and risk prevention as a constraint to economic and other development, reducing land-use values [3]. An instructive example of how risk-scapes proliferate and expand is the case of mixed forest–housing areas exposed and vulnerable to forest fires in the Mediterranean Region.

Both vulnerability management and resilience-building presuppose preventive and preparedness responses to disasters (although resilience is mostly apparent in the relief and recovery phase). However, prioritizing and implementing such proactive measures is only possible in the case of a widespread culture of preparation for adversity and contingencies. Especially in affluent societies, this is rarely the case, and the political leadership usually puts attention and financial support on positive prospects of potential development gains,

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not on the avoidance of losses [4]. This missing culture of anticipatory preparation for adversity is the third reason for the lack of attention to vulnerability and resilience.

The fourth reason for the lack of preparedness comes from the difficulties in building and practicing community and personal resilience as a result of the lack of or unequal distribution of the necessary resilience capital [5], i.e., physical (e.g., dwellings, public infrastructure facilities), social (e.g., networks, reciprocity, trust, social relations), political and institutional (e.g., normative framework, competences, organizational capacity), and financial capital (e.g., savings, income, subsidies, funding).

Finally, activation of both the public and private sector for vulnerability management and resilience-building necessitates sufficient knowledge on the part of the respective actors: what are the major local hazards? Who is vulnerable to these hazards, and why? What changes, by what means, might reduce vulnerability and potential disaster losses? Which actors are the most effective and efficient to introduce these changes, at what level? What are the most appropriate resources (resilience capital) to engage in resilience-building, and how can the vulnerable actors secure accessibility to these resources? The lack of knowledge on the above issues or partiality of knowledge by the actors at risk, including experts and management authorities, is an additional explanation of the lack of attention to vulnerability reduction and the missing policies for resilience-building.

The basic objective of the Special Issue is to pave ways to DRR through vulnerability reduction and resilience-building (from the level of a household and a social group to the international level) versus a wide range of disaster risks.

The first contribution by Gavriil Xanthopoulos, Miltiadis Athanasiou, Alexia Nikiforaki, Konstantinos Kaoukis, Georgios Mantakas, Panagiotis Xanthopoulos, Charalampos Papoutsakis, Aikaterini Christopoulou, Stavros Sofronas, Miltos Gletsos, and Vassiliki Varela focuses on forest fires in mixed forest residential areas on the island of Kythira, Greece, to elevate prevention and preparedness policies and actions targeting vulnerability and enhancing resilience. The authors criticized the obsession of the Greek state with the fire-suppression component/stage of the forest fire risk management cycle by referring to the metaphor "the fire-fighting trap" as a quick fix (rather than a long-term management strategy), inducing negative, unintended consequences. The authors proposed a road map of successive actions to upgrade the prevention and preparedness levels of the forest-fire-prone island. These include: (a) the construction of a forest fuels map to serve as a forest fire hazard information tool; (b) vulnerability assessment of a sample of building structures in settlements exposed to potential fires; (c) systematic information of the locals to alter their perceptions on risk and their housing vulnerability and to motivate them toward preparing their homes for a potential event. The authors emphasized voluntary action and community participation in decision making for proactive measures and their implementation. The authors acknowledged that several countries, including Greece, lag behind in voluntarism and community involvement in forest fire risk prevention and preparedness efforts. However, they argued that this abstention from knowledge and action by the community members at risk should change, predominantly the ignorance of their vulnerability and their capability to mitigate it. To that end, the authors proposed personalized risk-assessment information dissemination, i.e., a risk assessment for each property. They also proposed motivation by example as effective means for raising awareness and recruiting volunteers for preventive and preparedness action. Finally, the authors emphasized that the risk-communication strategies should be tailored to the at-risk communities' skills, habits, norms, beliefs, and risk culture.

While the first article focuses on efforts to persuade communities to turn their interest and financial requirements towards preventive and preparedness measures for vulnerability reduction—instead of only expecting state emergency action at times of difficulty—the second contribution of this Special Issue focuses on the obstacles to building resilience at the local level. Gerard Hutter, Alfred Olfert, Marco Neubert, and Regine Ortlepp considered tensions at the interface of science and practice as a major obstacle to operationalizing resilience. They started their research note assuming that building resilience is a complex

social change generated by motors (e.g., teleological, dialectic, etc.). Considering this social change through the lens of Strategic Spatial Planning, they found tensions that were associated with (a) diverging mindsets towards planned social change (originating from different institutional structures, etc.), (b) trade-offs implied by the multiplicity of hazards bedeviling a community and the variety of community agents' interests, and (c) the complexity involved in knowledge integration (due to the diversity of knowledge contents, frames, and approaches). The authors tested their assumptions about tensions between science and practice in resilience-building with a specific project example, "the Heat Resilient City" (HRC), which dealt with summer heat stress and proposed three ways out of the deadlocks: developing a strategic focus, setting priorities, and negotiating a compromise.

An especially enlightening component of the article is the analysis of the risk knowledge issue: the inconsistencies between knowledge from science and practice, compartmentalization of knowledge among citizens, business organizations, public institutions, and scientific experts, as well as other difficulties involved in risk knowledge integration. Under these circumstances, the reliability of the views and advice of experts was challenged, and the authors suggest that risk knowledge integration in pre-disaster terms should be considered not only as a technical exercise with objective results but as a "highly political and contested endeavor", too.

The closely related issue of objective versus subjective characterization of specific social groups as vulnerable, at risk, risky, etc. under pandemic conditions, is discussed by Katarina Giritli Nygren, Maja Klinga, Anna Olofsson, and Susanna Öhman in the third contribution to elevate the social construction of such characterizations and implications for the elderly care system. The authors focus on the early stages of the COVID-19 pandemic and examine the related articles and reports in three Swedish newspapers published during 2020. The social group of concern is the elderly, and the methodology on which the study is based is corpus-assisted discourse studies (CADS), which is actually a combination of corpus linguistics and discourse historical analysis. The basic objective was to explore the discursive formations of the elderly versus the risk of the pandemic in the Swedish media. The authors wondered, "to what extent are the elderly (as an entity) really at risk and vulnerable?" They attempted to find whether the epistemic conditions of health vulnerability and risk to life for the elderly were amplified/emphasized or attenuated in the corpus. Their findings (referring to the mass media) confirmed other findings from similar studies carried out elsewhere. The elderly were considered as a homogenous group, and the collocating words used were fragile, vulnerable, ill, exposed to infection, not full-fledged members of the society, and lacking the ability to act. On the other hand, the authors remarked that reference by the media to "our elderly" as a risk group that should be protected is a form of political inclusion prioritizing and safeguarding the native elderly, over or instead of other vulnerable groups such as immigrants.

The fourth contribution by Efthymios Karymbalis, Maria Andreou, Dimitros -Vasileios Batzakis, Konstantinos Tsanakas, and Sotirios Karalis deals with the hazard and exposure components of risk in the case of flood in the catchment of Megalo Rema, East Attica, Greece. The authors' attention was on the scientific dimensions of risk, and the most important result of their work was the demarcation and mapping of flood hazard zones as a necessary background for local level risk assessment and risk-sensitive land-use planning. Their methodology was Multi-criteria Decision Analysis combined with GIS. The factors/parameters considered and taken into account as the most influential were slope, elevation, distance from stream channels, geological formation, and land cover. Particularly, land cover is a variable affected by human interventions, evidencing the dependency of flood hazards and exposure on the human factor. The authors pointed to the highly and very highly exposed-to flooding areas (44% of the total catchment) as relatively low-lying, gently sloping, and extensively urbanized, and which host the densely populated settlements in the catchment of Megalo Rema. The authors adhered to their methodology as an effective tool for flood-risk-informed land use and spatial planning and

as a necessary background for flood risk-management strategies and action plans. Indeed, flood-hazard and exposure maps are an essential part of (objective) risk information, a valuable tool for determining the areas and infrastructure for which studies of territorial and technical vulnerability should follow, and a basic awareness tool to back public and private pre-disaster responses to flood risk.

The fifth contribution by Funda Atun and Chiara Fonio returns to issues of disaster risk awareness, risk perception and culture, and resilience practices built on subjective risk. This time, the social group of concern was Turkish migrants living in Northern Italy, their preparedness level, risk awareness, and their (probably resilient) behavioral patterns during emergencies. The methodology employed by the authors included a face-to-face questionnaire with 544 individual respondents and focus groups meetings with various socio-cultural groups. The methods were applied at three different urban scales: regional, community, and household. The questionnaire gathered information on the Turkish community's socio-demographic features, their disaster experience, preparedness, awareness, and their potential behavior during an emergency. On the other hand, the purpose of the meetings was to gain in-depth knowledge on the awareness, needs, feelings, beliefs, behavioral patterns in an emergency, and priorities. The most crucial query to the participants (about their risk perception) was, "what is a disaster for you?" Most of the respondents did not refer to a specific hazard as a disaster but rather to human-induced adversities such as migration and islamophobia. Floods and earthquakes were considered by the participants as the most probable risks, but there was a widespread lack of interest among the migrants in preparedness actions. Coping with linguistic and other cultural barriers was a key factor for the improvement of their preparedness.

Of the other findings of the work, one may pick out the fact that the social network is the main resource of Turkish migrants in case of emergency, especially for those who do not speak the local—Italian—language. However, while a strong sense of community provides migrants with some resilience resources, isolation from the domestic culture and social networks may be a barrier to resilience-building. In any case, and despite barriers, there is a high resilience potential among migrants due to their daily struggle to cope with existing inequalities. A major component of the migrants' resilience is their freedom to move in the case of a disaster.

Anna Fokaefs and Kalliopi Sapountzaki move forward to the next phase of the disaster management cycle, i.e., the emergency phase (the sixth contribution), to investigate the role of emergency information—released to the public and management authorities—in seismic crisis management. The authors discuss the uncertainty of seismic crises and, consequently, emergency seismic information. What are the differences between the models of seismic crisis communication adopted in earthquake-prone countries, how do these models handle uncertainty, and what are their effects on public perceptions, public and private emergency responses, and ultimately, on disaster management? To offer convincing answers, the authors presented and compared the seismic crisis communication models and strategies of Greece and Japan. First, they presented the two systems in terms of the sources, means, content, and mode of emergency information communication; then, they addressed and analyzed the successes and failures of each system during operation. This second analysis was based on actual experiences of seismic crisis management in the two countries.

The work confirmed that the major challenge of the seismic crisis period is how to handle uncertainty from multiple origins: a lack of knowledge and data, especially in the first post-event minutes; inherent variability present in the seismic phenomenon; ambiguity due to different knowledge frames of experts and public perceptions; technological gaps and failures; and coordination and governance barriers. The work evidenced that the highly centralized emergency communication systems have both merits and weaknesses. Among the latter is the fact that they allow only limited feedback from local-level empirical data. The recommendations for emergency communicators and managers—in the final section of the paper—on how to reduce or handle uncertainty represent a significant part of the added value of the article.

The issue of "objective" risk information to feed development and spatial planning returns with the seventh contribution by Adriana Galderisi and Giada Limongi. The theme in focus was not the hazard and exposure but the exposure and vulnerability components of risk within a multi-hazard context. The authors opted for an indicator-based method to carry out a comprehensive analysis of exposure and vulnerability in urban areas prone to multiple hazards. The work acknowledged the multiple facets of vulnerability (physical, social, systemic) that are critical for spatial planning and built sets of spatialized data and information that can be combined into different output maps, from maps showing the vulnerability features of selected elements (e.g., housing units) to comprehensive maps showing the overall levels of exposure and vulnerability. The authors used the Phlegraean Fields, a large volcanic area located in the western part of the metropolitan city of Naples, Southern Italy, as a testing case study area. The area represents a multi-hazard urban environment of high exposure because, on top of the volcanic hazard, it is prone to other natural and manmade hazards (earthquakes, landslides, industrial hazards, etc.), and it features high population density and very important historical, archaeological, and natural heritage. Application of the methodology resulted in a series of thematic maps illustrating "hotspots" in terms of exposure and several aspects of vulnerability to single and multiple hazards.

The basic value of the article rests with the determination of the spatial dimensions of several aspects of vulnerability and exposure to single and multiple hazards, their translation into sets of indicators, as well as their selective integration and mapping with the help of the GIS tool. The ultimate aim was to feed spatial planning with risk knowledge, thus building so-called risk-informed or risk-sensitive spatial planning. However, as the authors admit, the methodology does not capture interactions among hazards, causing secondary hazards and new interactions with vulnerability resulting in catastrophic impacts and tertiary hazards, etc. As already mentioned, epistemic risk knowledge carries uncertainty and limitations.

Maria Kousis and Katrin Uba discuss the changes in environmental concern and activism during hard times, which, more often than not, are periods of increasing livelihood vulnerability. With their (eighth contribution), the authors oppose the argument that hard economic times are obstacles to environmental activism. To this end, the authors compare Environmental with non-Environmental Alternative Action Organizations (AAOs) using a cross-national dataset of 4157 hubs-retrieved AAOs active during the economic crisis in France, Greece, Germany, Italy, Polland, Spain, Sweden, Switzerland, and the UK. Using empirical data from a comparative European Commission project shed light on environmental activism engaged in participatory solidarity initiatives reflecting a transformative capacity (economic, environmental, socio-political) for resilience, mostly at the local level. The authors concluded that environmental protection and sustainable development were not neglected during economic hardship. Difficult times provide opportunities for EAAO activism to broaden its scope of action by focusing on alternative practices and lifestyles, simultaneously benefiting basic social needs, livelihoods, and the environment. The authors suggested that the findings of their study could be useful for any "hard times" occasion, not only that of an economic crisis but also public health and climate crisis or cases of natural or manmade disasters. The new focus of EAAOs on direct solidarity action seems to be promising in the long-term to build collective resilience to cope with or manage post-disaster crises, climate crises, etc. Compared to non-Environmental, the EAAOs tend to be informal and focused on contention and protests mobilized by the intensity of the 21st-century challenges and their catastrophic potential.

The ninth contribution revisits the issues of risk perception and awareness in an insular, multi-hazard context: the Azores island facing both telluric (volcanic) and climate-related hazards. The key research questions that the authors Ante Ivčević, Isabel Estrela Rego, Rui Gaspar, and Vania Statzu attempted to answer were: wow does the local population perceive the threat of the natural hazards present in Azores? What is the relationship between local risk awareness and risk-mitigation strategies? The authors conducted a

web-based survey with a relevant questionnaire administered to a sample of Azoreans. The basic conclusion was that although risk awareness alone is not enough for measures to be implemented, it may be an important initial motivation for locals to accept and support the implementation of mitigation measures.

Altogether, 201 individuals responded to the questionnaire, with their ages ranging from 18 to 45 years. On average, respondents considered earthquakes and Climate Change as the most likely extreme natural phenomena to occur in their area. The least expected phenomena were wildfires, droughts, and tsunamis, while the occurrence of volcanic eruptions and heatwaves was mostly perceived as unknown. The most important secondary question raised out of the participants' responses was how to reduce the gap between having hazard knowledge and using this knowledge to implement precautionary measures. The authors suggest that this gap may be related *"to the locals' low perceived control and self-efficacy as they are somewhat unable to overcome the structural and psychological barriers to mitigation strategies implementation".* An interrelated research query is much the locals are willing to pay to protect their house against risks (e.g., Climate Change risks) by using precise methods such as contingent valuation exercises. The above assumptions and questions, raised for both telluric and climate-related hazards, open a very important window for research to follow.

The last (tenth) contribution written by Stefan Greiving, Leonie Schödl, Karl-Heinz Gaudry, Iris Katherine Quintana Miralles, Benjamín Prado Larraín, Mark Fleischhauer, Myriam Margoth Jácome Guerra, and Jonathan Tobar deals with countries and territories jeopardized by multiple hazards and dynamic vulnerability processes, hence high-disaster-risk levels. The main concern of the authors was to find paths towards coordinated and integrated action originating from spatial planning and emergency management to improve the performance of countries such as Chile and Ecuador in policy goals coming from UN-ISDR and UN SDGs. The authors argued that while both countries have shown considerable progress in the implementation of the UN strategies, multi-risks, however, are rarely considered, and there is still increasing vulnerability due to the expansion of informal settlements. To compare the two Latin-American countries (sharing a similar risk profile as they are part of the Pacific Ring of Fire), the authors put special attention on their largest Metropolitan Regions, Quito and Santiago de Chile, due to their hazard profile, high vulnerability as economic powerhouses of their countries, and the relatively high-risk management capacities. The guiding research questions were: what are the root causes of vulnerability and risk in Chile and Ecuador? How do these two countries perform in regard to the Sendai Framework global targets E (existence of adequate national and local DRR strategies) and G (availability of and people's access to multi-hazard early warning systems and disaster risk information)? The authors (a) conducted a desk-top analysis of national policy documents and strategies as well as local risk-management and land-use plans for Quito and Santiago de Chile, (b) collected primary data for in-depth evaluation of context-specific assessment and management strategies during a field trip, organized two workshops in Ecuador with central and local level public officials, and (c) conducted expert interviews with stakeholders from various agencies to validate empirical findings.

Based on their analysis, the authors arrived at a serious criticism of the global monitoring system destined to achieve UN-ISDR strategies. According to their words, "*the global monitoring is primarily designed as enforcement control (input indicators) combined with a control of target achievements (output indicators), but lacks a real control of the effectiveness of the existing disaster risk management system.., this cannot be done based on purely quantitative variables. There is a need of local knowledge gathered from document analyses, surveys and interviews*". Indeed, how can the current global monitoring system of indicators capture problems of the institutional language/terminology such as those identifying risk with threat; or problems related to the lack of active involvement and empowerment of citizens in identifying risk areas and evacuation routes? In addition to the indicators, there is a need for quality criteria to be addressed by the national reporting requirements.

As a general message from the Special Issue, the reader should keep in mind that both epistemic risk information/knowledge (objective risk) dissemination and risk perception (subjective risk) understanding are key factors to vulnerability management and resilience-building by public and private entities at all spatial scales and in every stage of the risk-management cycle. A lack of risk information accessible to all concerned and the absence of an understanding of risk-perception limitations by managers hampers (anticipatory) vulnerability management [6] and resilience-building.

List of Contributions

1. Xanthopoulos, G.; Athanasiou, M.; Nikiforaki, A.; Kaoukis, K.; Mantakas, G.; Xanthopoulos, P.; Papoutsakis, C.; Christopoulou, A.; Sofronas, S.; Gletsos, M.; Varela, V. Innovative Action for Forest Fire Prevention in Kythira Island, Greece, through Mobilization and Cooperation of the Population: Methodology and Challenges.
2. Hutter, G.; Olfert, A.; Neubert, M.; Ortlepp, R. Building Resilience to Natural Hazards at a Local Level in Germany—Research Note on Dealing with Tensions at the Interface of Science and Practice.
3. Giritli Nygren, K.; Klinga, M.; Olofsson, A.; Öhman, S. The Language of Risk and Vulnerability in Covering the COVID-19 Pandemic in Swedish Mass Media in 2020: Implications for the Sustainable Management of Elderly Care.
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5. Atun, F.; Fonio, C. Disaster Risk Awareness: The Turkish Migrants Living in Northern Italy.
6. Fokaefs, A.; Sapountzaki, K. Crisis Communication after Earthquakes in Greece and Japan: Effects on Seismic Disaster Management.
7. Galderisi, A.; Limongi, G. A Comprehensive Assessment of Exposure and Vulnerabilities in Multi-Hazard Urban Environments: A Key Tool for Risk-Informed Planning Strategies.
8. Kousis, M.; Uba, K. (Non)Environmental Alternative Action Organizations under the Impacts of the Global Financial Crisis: A Comparative European Perspective.
9. Ivčević, A.; Rego, I.E.; Gaspar, R.; Statzu, V. Telluric and Climate-Related Risk Awareness, and Risk Mitigation Strategies in the Azores Archipelago: First Steps for Building Societal Resilience.
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Article

Innovative Action for Forest Fire Prevention in Kythira Island, Greece, through Mobilization and Cooperation of the Population: Methodology and Challenges

Gavriil Xanthopoulos [1,*], Miltiadis Athanasiou [2], Alexia Nikiforaki [2], Konstantinos Kaoukis [1], Georgios Mantakas [1], Panagiotis Xanthopoulos [1], Charalampos Papoutsakis [1], Aikaterini Christopoulou [1], Stavros Sofronas [1], Miltos Gletsos [2] and Vassiliki Varela [1]

[1] Hellenic Agricultural Organization "Demeter", Institute of Mediterranean & Forest Ecosystems, Terma Alkmanos, 11528 Athens, Greece; kako@fria.gr (K.K.); mage@fria.gr (G.M.); panosxant@hotmail.com (P.X.); xarispap11@hotmail.gr (C.P.); aikatchr@gmail.com (A.C.); sofronass@gmail.com (S.S.); vvarela@otenet.gr (V.V.)

[2] Hellenic Society for the Protection of Nature, Nikis 20, 10557 Athens, Greece; info@m-athanasiou.gr (M.A.); alexia.nikiforaki@gmail.com (A.N.); mgletsos@eepf.gr (M.G.)

* Correspondence: gxnrtc@fria.gr; Tel.: +30-210-779-3142

Abstract: The island of Kythira in Greece suffered a major forest fire in 2017 that burned 8.91% of its total area and revealed many challenges regarding fire management. Following that, the Hellenic Society for the Protection of Nature joined forces with the Institute of Mediterranean and Forest Ecosystems in a project aiming to improve fire prevention there through mobilization and cooperation of the population. This paper describes the methodology and the results. The latter include an in-depth analysis of fire statistics for the island, development of a forest fuels map, and prevention planning for selected settlements based on fire modeling and on an assessment of the vulnerability of 610 structures, carried out with the contribution of groups of volunteers. Emphasis was placed on informing locals, including students, through talks and workshops, on how to prevent forest fires and prepare their homes and themselves for such an event, and on mobilizing them to carry out fuel management and forest rehabilitation work. In the final section of the paper, the challenges that the two partners faced and the project achievements and shortcomings are presented and discussed, leading to conclusions that can be useful for similar efforts in other places in Greece and elsewhere.

Keywords: fire prevention; fire statistics; forest fires; public participation

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1. Introduction

Forest fires are a natural process of most forest ecosystems around the world but at the same time, due to their environmental, social, and economic impacts, they constitute a significant natural hazard, a problem that societies have to face. In the last two decades many scientific studies have affirmed that there is a worsening trend regarding this problem [1–3]. Whereas, Doer and Santin [4] questioned the widely held perception, both in the media and scientific papers, that wildfires are an accelerating problem due to increasing fire occurrence, severity and resulting losses, multiple wildfire disasters in the last few years have provided clear evidence that the wildfire problem is globally on the rise. Extreme fires that exceed by far the capacity of even the most competent firefighting mechanisms, often causing huge damage and multiple fatalities in addition to vast burned areas, tend to become commonplace [5–8] while, in parallel, significant fires have started to occur in unusual places, such as countries in the northern latitudes [9–11]. Such large fires do not only have devastating effects on vegetation, soil erosion, flooding [12] water quality [13], carbon sequestration [14], etc., but they also upset the economy, function and psychology of local societies [15,16].

The inability of firefighting mechanisms to control fires that exceed certain levels of fire behavior, as summarized by Tedim et al. [17], leads, as a rule, to efforts aiming to increase these threshold levels through better organization, faster response, more resources, and adoption of technological advances, alas at an ever increasing cost. This approach, merely directed to fire extinction without due attention to prevention, can be described by the metaphor of the "firefighting trap". This term, in business, describes a "quick-fix" management strategy, which focuses on fixing rather than preventing problems, often resulting in unintended negative consequences [18]. In the realm of forest fire management, such a strategy can initially appear successful as it is likely to reduce damage in the short term, but in the long term it fails to address the roots of the increasing wildfire potential [19] resulting in the so-called "fire paradox" [20,21]. This problem has been documented clearly and current scientific thinking calls for shifting the focus from fire suppression to mitigation, prevention, and preparation, as such a policy is more likely to reduce the negative socioeconomic and ecological effects of fire than the current, largely one-dimensional, focus on fire exclusion [22].

An emphasis on forest fire prevention is the alternative approach for mitigating the problem of forest fires. According to the FAO's Wildland Fire Management Terminology, fire prevention includes "all measures in fire management, fuel management, forest management, forest utilization and concerning the land users and the general public, including law enforcement, that may result in the prevention of outbreak of fires or the reduction of fire severity and spread". Fire prevention is a term widely found in the international scientific literature, reflecting its importance. Most of the research efforts and publications are devoted to technical aspects such as fire risk prediction and mapping, fire detection, etc. Regarding forest fuel management, scientific studies have clearly shown the influence of the condition of forests and their fuels (after fuel treatment or previous fires) on fire behavior and severity [23,24], so forest and fuel management is usually part of fire prevention programs. In wildland–urban interface areas in particular, properly implemented fuel treatments can play a significant role in protecting assets, reducing fire severity and increasing forest resilience [25].

In addition to fuel management, fire prevention aims at effective reduction of fire starts, improved safety, and mitigation of damage, especially when a fire escapes initial attack and reaches a wildland–urban interface area. All these prevention elements are closely tied to people, their knowledge and their attitudes. Since, in most places in Europe [26] and around the world [27] the vast majority of fires are caused by humans, many fire prevention programs include a strong component focused on people [28,29]. The research work devoted to this effort is probably less than that on technical fire prevention issues, but there are still numerous efforts to analyze behaviors at individual and community levels [30–38]. On the other hand, there are many examples of applied efforts that aim to educate, motivate and guide people to contribute to fire prevention, by reducing fire ignitions, at personal and community scales. Information about them is quite often not in the form of scientific publications but in the form of "grey literature" (articles, reports, essays, handbooks, field guides, internet sites, etc.). Examples are the training manual published by the International Tropical Timber Organization (ITTO) on "Forest fire prevention for Community" [39]; the report of Hesseln and Ergibi (2017) [40,41] on the "FireSmart-ForestWise" program in Canada; the "Wildfire Risk to Communities" website created by the USDA Forest Service under the direction of Congress [42]; the "Firewise USA" site of the National Fire Protection Association (NFPA) [43]; and the "Community Fireguard" program of the CFA in Australia [44].

The Mediterranean countries of Europe are among those where forest fires have become a major problem. Fire suppression receives a lot of attention and has become the focus of heated debates, especially during and after difficult fire seasons, and this happens with increasing frequency due to aggravation of the conditions that lead to major fire disasters. In general, there is a consensus that in regions with Mediterranean-type climate the currently prevailing emphasis of fire management on suppression is doomed to fail, so

a shift towards prevention, and preparation is both logical and pragmatic. Accordingly, policy and expenditures should be balanced better between suppression and mitigation of the negative socio-ecological impacts of fire [18,22,45].

Aggressive forest fire behavior in recent years, whatever the reason, is a major problem for fire managers. In Greece, however, the forest fire management reality includes an additional challenge: there are more than 200 inhabited islands, some of them at considerable distance from the mainland and the abundant firefighting resources there. Thus, in many cases fire suppression cannot be as effective as on the mainland, at least for as long as it takes for reinforcements to arrive. Thus, fires that escape initial attack have great potential to grow and threaten settlements and infrastructures. Obviously, the only option for such islands, other than building-up a disproportional and costly fire suppression capacity that will be idle most of the time, is to maximize the effort for fire prevention and effective initial attack.

The work described here focused exactly on developing and testing an approach for fire prevention on one such Greek island, based to a significant extent on the innovative involvement of local volunteers. The methodology, outcomes, and challenges that were faced are presented in this paper.

2. Materials and Methods

The work focused on the island of Kythira, which lies south of Peloponnese, Greece, has an area of 277.28 km^2 and a population of 3973 people according to the most recent (2011) census. The number of people on the island increases steeply in the summer with the return of Kythirians from Athens and the foreign countries to which they have emigrated, and with the addition of numerous tourists. Kithira is an example of a remote island with relatively poor connection to the mainland by boat or by air. Not surprisingly, it has a long history of significant forest fires. In 2017, it suffered a major fire that burned a large part of the island. It started on 4 August, next to the hospital of Kythira near the village of Aroniadika (location "Pitsinades") and burned 2471 ha (8.91% of the island) (Figure 1), after changing its main spread direction many times and threatening villages, homesteads, and the historic monastery of Panagia Mirtidiotissa. A large part of the fire perimeter stopped at the sea. The fire was officially declared as extinguished 18 days later.

The fire of 2017 revealed many weaknesses regarding fire management on the island. In the years that followed, the local authorities and other state agencies started an effort to improve prevention and suppression. Initially they focused on flood protection works, and then they tried to improve prevention infrastructures such as water tanks, fire hydrants, forest roads etc. On the other hand, the Hellenic Society for the Protection of Nature (HSPN), the oldest national environmental NGO in Greece, joined forces with the Institute of Mediterranean and Forest Ecosystems (IMFE) of the Hellenic Agricultural Organization "Demeter" for a project aiming at fire prevention improvement, but with a different emphasis compared to that of the authorities: they mainly focused on mobilization of the citizens. They were inspired to a large extend by the prevention examples with public involvement mentioned above, realizing, however, that as people and conditions are different, the local context must be taken into consideration, innovating where needed.

Forest fire prevention refers to all the actions carried out before the start of a fire that aim to reduce the probability of a fire starting, the potential for quick growth and aggressive behavior if a fire starts, and the potential for damage in case of a fire. Furthermore, it includes the existence of effective fire detection and good planning for a quick response and effective initial attack. Being less visible than suppression, fire prevention is often neglected.

Fire prevention is quite broad and complex. It has a significant planning component and includes physical works such as forest road maintenance, securing water sources (e.g., constructing water tanks, water ponds, fire hydrants, etc.), forest and fuels management, as well as a host of activities that focus on people. This is because most fires are human-caused, and the safety of people is a top priority of forest fire management. All these three components must be present in order to achieve effective and efficient prevention.

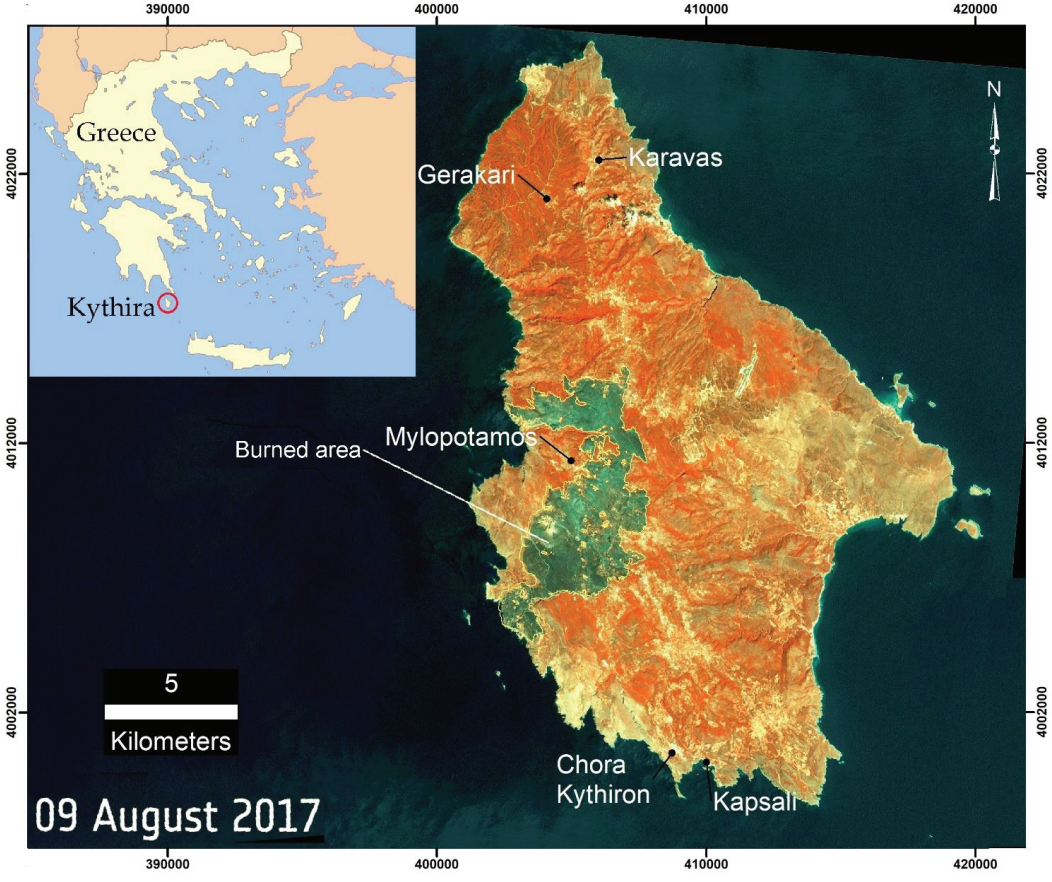


Figure 1. A map of Greece showing the location of Kythira, in-laid in an annotated false color composite image of the island, captured by the Copernicus Sentinel-2 satellite pair, immediately after the 4 August 2017 fire. The scar of the fire is clearly visible. (Image source: The European Space Agency https://www.esa.int/ESA_Multimedia/Images/2017/08/Kythira_wildfires, accessed on 1 December 2021).

In the frame of the project, as there was no capacity (mandate, manpower, funding) to perform physical works, it was decided to focus on the planning component and to work with the people. Physical works require much more funding and they are handled anyway by the local authorities that receive funding from the state budget through the General Secretariat for Civil Protection. Thus, the objective was to fill the existing gap, by relating scientific knowledge to and working with people, innovatively blending the two components where possible, in order to reduce the number of fires and burned area, and to mitigate damages. In doing so, it was intended to demonstrate, making prudent use of the small project budget, the efficiency that can be achieved through this approach.

The methods used to pursue the aims of the project followed two directions. The first, was an effort to understand and analyze the fire problem and the conditions (e.g., fuels, topography) on the island, in support of fire prevention and presuppression planning. The second included all the efforts that aimed to mobilize the people on the island for fire prevention. Most of the work concentrated in the area of three main settlements, as was planned at project inception, but there were also activities that covered the whole

island. The three settlements are (a) Karavas and Gerakari in the north of the island, (b) Mylopotamos at the center, and (c) Chora Kythiron and Kapsali in the south (Figure 1).

More specifically, the methods focusing on understanding and analyzing the fire problem consisted of:

- Documentation of the fire problem in Kythera, based on an analysis of Forest Service and Fire Service forest fires statistical records for the last 20 years and a search for reports on forest fires in available newspaper records for the last 50 years. This was followed by an examination of topography and long-term meteorological data, resulting in identification of the conditions (place and time) associated with very high fire hazard.
- A field campaign for identification and documentation of the forest vegetation and fuel situations on the island, followed by assignment of the corresponding fuel models to each such situation. The fuel model description follows the concepts used in the US Forest Service fire behavior prediction and simulation systems (BehavePlus [46,47], Farsite [48], Flammap [49]) where a fuel model is used as input representing fuels in Rothermel's mathematical model for predicting fire spread in wildland fuels [50]. The fuel models used have been developed specifically for Greece [51,52] and have undergone testing against real-world fires [53]. With the help of photo keys [51], in a manner similar to [54], the vegetation conditions were matched to fuel models. Where a good match between fuel situations and existing fuel models could not be found, a new fuel model was created for Kythira following the methodology proposed by Xanthopoulos and Manasi [55]. This was the case of evergreen shrubs with a height up to 80 cm. The fuel models were used with BehavePlus, with weather and slope conditions typical for the island, in order to estimate potential fire behavior.
- Development, for the first time in Kythira, of a forest fuels map, based on the identification of forest fuel situations above. The map was created through manual interpretation/digitization, in a GIS environment, utilizing georeferenced field photos of fuel situations for training the photo-interpreters. A recent forest map of the Forest Service was used as basis, with further distinction and delineation of fuel situations based on Google Earth images. For example, photointerpretation allowed distinction of the vegetation category of evergreen shrubs into tall, low and very low shrubs, corresponding to different fuel models. The representativeness of the fuel map was then evaluated in the field.
- Simulation of the spread of the 4 August 2017 fire using the G-FMIS fire spread simulator [56] after developing a good documentation of its real evolution through mass media reports, testimonies of witnesses, photos, and videos. Inputs to the simulation were the fuels map, the digital elevation model (DEM) for Kythira, and the meteorological conditions. The objective was to examine the possibility of achieving a realistic simulation before using G-FMIS for further simulations.
- Carry out fire spread simulations starting at selected high-risk locations in the vicinity of the three selected settlements, using the G-FMIS fire spread simulator. The simulations were based on the fuels map, the DEM, and plausible average worst fire weather scenarios.
- Development, using GIS, of a map of safe separation distance (SSD) between the potential flame and the firefighters, based on vegetation height, slope and wind [57,58].
- Evaluation of the risk of destruction of nearly all the buildings (N = 610) in the three settlements through a structure-by-structure assessment, with the help of small teams of volunteers. The volunteers were given a standard form which they had to fill for each structure. The form lists in classes the main elements affecting its risk in case of fire (properties and distance of surrounding vegetation, topography, characteristics of the building that affect its vulnerability, ease of access, fire protection infrastructure, etc.). The volunteers were first trained how to fill the forms. Then they were given a satellite image from Google Earth of the settlement they had to visit with the structures numbered in sequence. They visited each structure, took photographs and filled in

the corresponding form. A scoring system was used to assess the risk of destruction of the structure. The result was double checked by the fire experts of the research partners through the photos and with the help of Google Earth. Additionally, a field visit allowed verification of the results for a sample of structures. The final assessment for each structure was then entered in a risk assessment form to be distributed to the structure owner. The assessment form informed the owner of the risk due to vegetation and due to the vulnerability of structure elements, as well as of the overall risk. It also offered recommendations on what needs to be changed to improve safety. Additionally, the form included a warning in case the owner would decide to stay and defend, recommending early evacuation in case of high-risk, hard-to-defend structures. These forms were distributed personally to each owner through the volunteers. The owners were also asked to fill in a short questionnaire with their opinion about the assessment and on their willingness to act to improve the safety of their structure.

- A confidential map showing the structures, color-coded according to their risk, was provided to the Fire Service. Further mapping identified areas of exceptionally high-risk, as a result of high SSD, concentration of vulnerable structures, and poor road access, where special planning is needed and early evacuation is advised. These maps were also delivered to the authorities.

The contribution of the volunteers to the assessment of the risk of structures also formed the link between the direct scientific input of the forest fire experts and the work that aimed to mobilize the citizens. This work included:

- A series of talks by the fire experts of the two partners to inhabitants of Kythira on fire prevention, at all three settlements, explaining the problem of forest fires, introducing the concept and the content of fire prevention and urging for mobilization and cooperation of the people. It was in the first meetings of this series that the teams of volunteers were formed.
- A series of talks to elementary and high school students, aiming to make them aware of the issue of forest fires, providing them with practical information on prevention and with simple and effective take-home messages. Each of these events was tailored to the corresponding student level and employed appropriate techniques with the help of professional environmental educators of the HSPN.
- Voluntary field activities by volunteers and students including reforestation of selected sites, and understory fuel management in selected stands along roads. The extent of both activities was limited as they are quite demanding. Their main objective was to foster a voluntary spirit.
- Production of two informative videos (a) on making a home that is situated near forest vegetation safe (12 min) and (b) on how a citizen should react if threatened by a fire in the vicinity (30 min). The videos were distributed to local media, were made available to the local authorities and to the volunteers and were also uploaded to YouTube. A third video was also produced, documenting all the activities of the project.
- Production of a four-page brochure with practical information on fire prevention specifically for Kythira.
- A series of articles about the forest fire problem in Kythera and its mitigation published in the local press and in the tri-monthly magazine of the HSPN.
- A series of interviews with local radio stations on the subject of fire prevention involving fire experts of the research partners' teams.

3. Results

3.1. Results of Past Fires Documentation and Analysis

The results of the scientific effort were multiple, useful and inspiring for the authorities and the people. The search for forest fire records in the newspapers and the analysis of the fire statistics revealed the patterns of fire on the island. For example, a fire on 8 August 1971 that burned about 2000 ha and threatened the monastery of Panagia Mirtidiotissa, was much like the 2017 fire that started on 4 August and burned 2471 ha in roughly the same

area, also threatening the monastery. This finding provided an excellent example in the talks to the people, showing that in a Mediterranean environment like that of Kythira, fire is a recurring phenomenon, so serious preparation regarding the safety of their homes and their personal readiness is well justified. Also, the search of the records showed that on a number of occasions fires trapped tourists in small, secluded beaches that dot the perimeter of the island having, due to the steep topography, only one access road. Evacuation by boats offered a solution in those cases but current planning should take this probability into consideration.

Regarding the fire statistics records, a total of 228 fires were recorded in the 2000–2019 period. Only six of them (2.6%) became very large (>100 ha), but they contributed 88.7% of the 6135.46 ha that burned in this period (Figure 2).

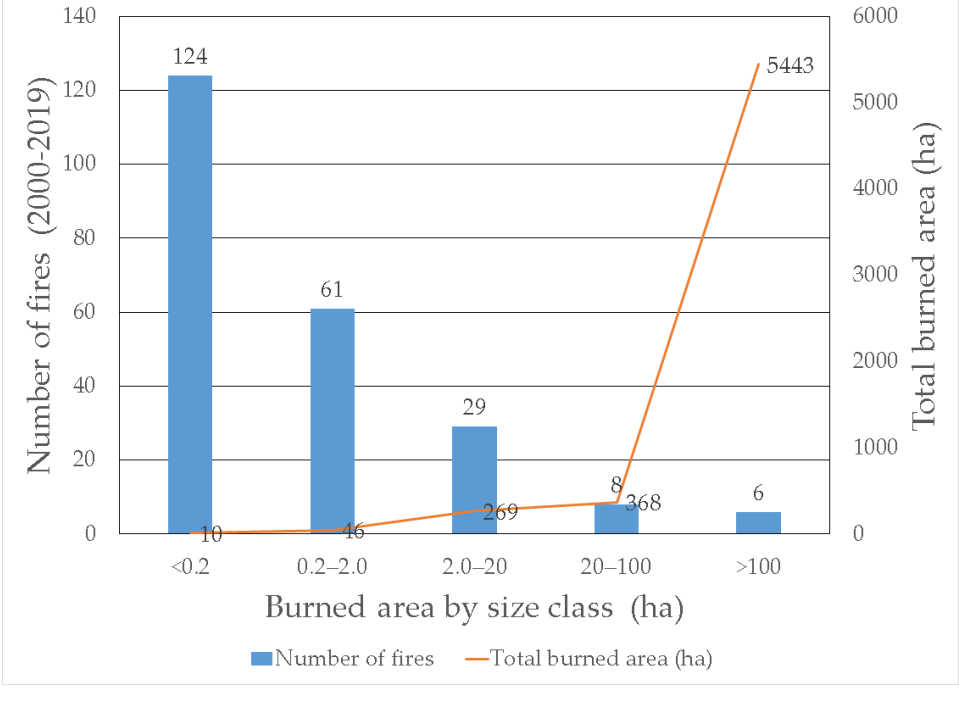


Figure 2. The number of fires in Kythira by size class and their contribution to the total burned area for the 2000–2019 period.

Regarding the burned area on Kythira, the total of 6135.46 ha, represents 22.07% of the whole area of the island. This percentage is much larger than the 6.13% figure for the whole country, for the same period, and is an indication of increased difficulty and/or shortcomings in the management of the fire problem on the island.

On the average, 19 fires occurred per each calendar month within the 2000–2019 period, having a fairly even distribution. May is an exception with only six fires in these 20 years, while July with 28 fires and August with 27, as expected, are the months with the highest fire frequency. However, the distribution is very different regarding large fires and burned area. With the exception of a 1804 ha fire that occurred on 23 June 2000, all the other large fires (>100 ha) occurred in August. Most of the large fires occurred in years characterized by a challenging fire season.

Regarding firefighting, Table 1 lists the nine fires, out of the total of 228 which received aerial firefighting. With the exception of the lightning-caused fire of Agia Moni, which

received initial attack drops by two light PZL M-18 Dromader aircraft and only burned a few square meters, all the other fires burned for more than 10 h. Also, strong aerial support was only made available for fires that grew to more than 10 ha. To a large extent, this illustrates the effect of the distance of Kythera from the central bases of aerial resources and supports the argument that effective prevention and strong initial attack are highly important for the island.

Table 1. The nine forest fires on Kythira, in the 2000–2019 period that received aerial firefighting support.

Area	Date	Fire Start	Fire Duration (Hours)	Burned Area (ha)	Helicopters	CL-415 or CL-215	PZL M-18	Aerial Resources (All)
Agia Moni	12 September 2018	14:50	5.5	0	0	0	2	2
Vrisi Mitaton	12 March 2018	11:14	10.9	0.4	0	2	0	2
Venergianika	9 July 2017	15:24	29.8	2.5	1	0	0	1
Friligianika	3 July 2016	09:44	28.9	2.6	0	2	0	2
Mantala	24 August 2019	19:29	84.7	12.0	3	2	0	5
Gerakari	9 November 2017	12:34	90.9	20.0	0	2	0	2
Aginara	9 October 2012	09:22	84.6	116.5	0	6	0	6
Melidoni	1 August 2013	15:23	101.1	251.0	1	2	0	3
Pitsinades	4 August 2017	10:55	411.1	2471.0	3	5	0	8

Examination of the prevailing wind conditions showed that in the summer months the wind blows mainly from a NE direction, falling under the well known "meltemi" wind pattern that is prevalent in the summer season in the Aegean sea, in Greece. However, as Kythira is located between the Aegean sea to the east and the Ionian sea to the west, westerly winds from the Ionian are the second most common. Whereas in the islands of the Aegean firefighters may count on the NE meltemi wind for their fire suppression planning, in Kythera, especially for larger fires lasting for many days, planning should consider the increased probability for wind shifts, as happened in the case of the large fire of 4 August 2017.

3.2. Forest Fuels Map

The forest fuel map that was developed for Kythera is shown in Figure 3. It is the first time such a tool became available for the island, and it can be very useful both for fire prevention planning and fire suppression. Table 2, provides a simple general correspondence of the fuel types with fuel models.

The limited areas of tall forest, cover 1.31% of the island and consist mainly of *Pinus halepensis* with an occasional mix of Eucalypt (*Eucalyptus globulus*). These forests are the result of earlier reforestation efforts. In some very limited spots there are only pine needles on the ground, and the bottom of the crown starts at 1–1.5 m. The height of the trees generally varies between 8–15 m and below their crown, as a rule, there is a thick evergreen shrub understory (Figure 4). The evergreen shrubs layer, both in the understory and in the open, consists of such species as *Arbutus unedo*, *Quercus coccifera*, *Pistacia lentiscus*, *Erica manipuliflora*, *Erica arborea*, *Juniperus phoenicea*, *Ceratonia siliqua*, *Genista acanthoclada*, etc. In all cases, in the summer, under even medium fire weather conditions, fires in the tall pine forests with such understory, burn as active crown fires, with the spread rate dictated by the shrub component. Thus, in Table 2, the tall forest fuel type was assigned to the "tall maquis" fuel model for fire modelling purposes. The values of the parameters of the fuel models are listed in Table 3 [51,52].

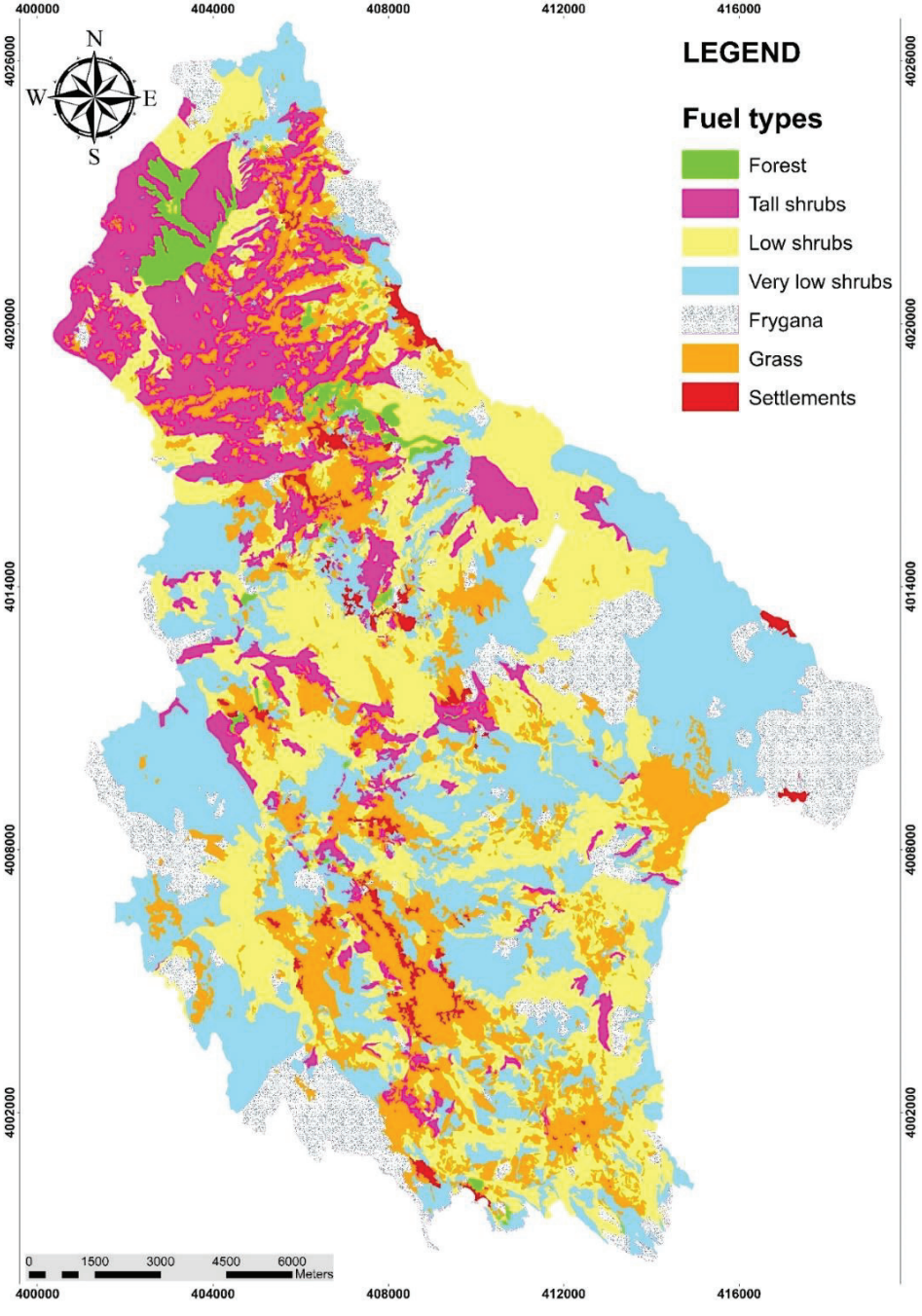


Figure 3. The forest fuel types map of Kythira.

Table 2. Correspondence of fuel types on Kythera with fuel models for Greece [51,52]. A custom fuel model was developed for Kythira for better representation of the "Very low shrubs (avg. height < 0.8 m)" fuel situation.

Fuel Type	Fuel Model
Tall forest (usually with shrub understory)	Tall maquis
Tall shrubs (avg. height > 1.5 m)	Tall maquis
Low shrubs (avg. height 0.8–1.5 m)	Low maquis
Very low shrubs (avg. height < 0.8 m)	Custom fuel model for Kythira
Phrygana (avg. height < 0.5 m)	Phrygana (*Sarcopoterium spinosum*)
Agricultural cultivations (grass)	Mediterranean grassland
Settlements	No burn area

Figure 4. An example of a *Pinus halepensis* stand with evergreen shrub understory near the settlement of Gerakari.

Table 3. The values of the fuel model parameters used in Kythira, adapted from [51,52].

Parameter / Fuel Model	Low Maquis (Model I)	Tall Maquis (Model II)	Phrygana (*Sarcopoterium Spinosum*) (Model V)	Mediterranean Grassland (Model VI)	Very Low Shrubs at Kythera
Dead fuel load <0.63 cm (1-Hr) (Mton/Ha)	9.91	17.88	3.50	4.82	3.06
Dead fuel load 0.63–2.54 cm (10-Hr) (Mton/Ha)	6.80	13.30	1.02	0.49	0.86
Dead fuel load 2.54–7.62 cm (100-Hr) (Mton/Ha)	3.60	8.5	0.28	0.00	0.00
Live Herbaceous fuel load (Mton/Ha)	0.00	0.00	0.00	0.00	0.00
Live Woody fuel load <0.63 cm (Mton/Ha)	7.70	10.60	0.85	0.00	9.79
Surface-area-to-volume-ratio for 1-Hr dead fuels (1/cm)	55	55	65	78	55

Table 3. *Cont.*

Parameter / Fuel Model	Low Maquis (Model I)	Tall Maquis (Model II)	Phrygana (*Sarcopoterium Spinosum*) (Model V)	Mediterranean Grassland (Model VI)	Very Low Shrubs at Kythera
Surface-area-to-volume-ratio for live herblaceous fuels (1/cm)	-	-	-	-	-
Surface-area-to-volume-ratio for live woody fuels (1/cm)	55	55	65	-	55
Fuel Bed Depth (cm)	102.19	203.58	40.00	27.53	39.34
Fuel moisture content of extinction (%)	34	34	20	14	33
Heat Content (J/G)	20,000	20,000	19,054	18,600	19,050

3.3. Testing of Fire Spread Simulation in Kythira

As mentioned earlier, the evolution of the 4 August 2017 fire was documented in detail mainly through photos and videos of known locations and time, offered by local volunteers, discussions with Fire Service personnel and other locals, and finally through mass media reports which had devoted significant live reporting time. The meteorological conditions were obtained from the local weather station. Using the G-FMIS fire spread simulator [56], which has been extensively tested in Greece, the fuel map, and the DEM of Kythira, the spread of the fire was simulated. The wind flow over the terrain was taken into consideration through the NUATMOS model (Ross et al., 1988) which is embedded in G-FMIS. The results of the simulation are shown in Figure 5. They were assessed as quite realistic.

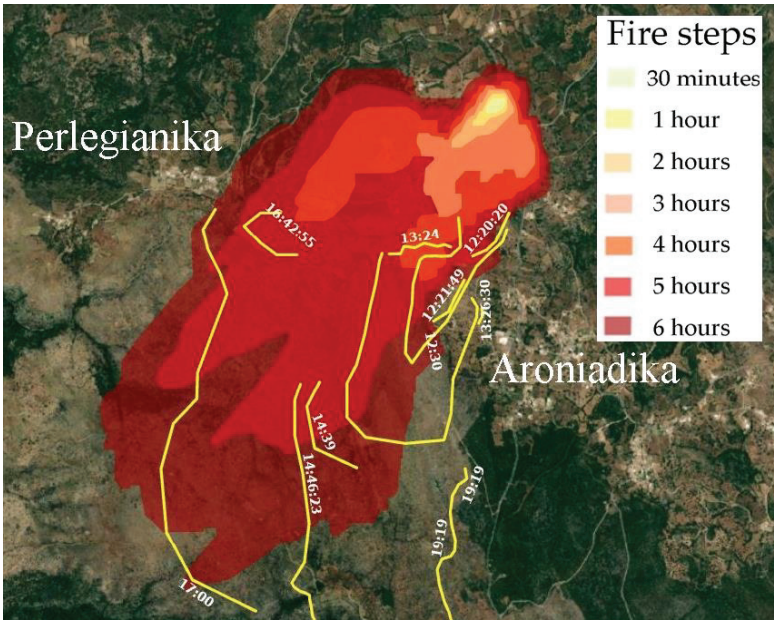


Figure 5. Comparison of the actual evolution of the perimeter of the fire of 4 August 2017 in Kythira (Pitsinades fire), which started at 10:55 am, with the simulated growth of the perimeter at regular intervals with the G-FMIS system, using the actual meteorological conditions of that day and the fuel map of Figure 3.

3.4. Simulations of Probable Fires in the Vicinity of the Three Settlements at Kythira

Having established the capability for reliable fire modelling on the island, the fuels map was then used in conjunction with a fire weather scenario similar to the difficult conditions during the 2017 fire, for fire spread simulations with G-FMIS, in the vicinity of the three selected settlements on the island. Two wind direction scenarios were used according to the prevailing directions during the summer (NE and W). For each case, an ignition point was selected, such that with the prevailing wind direction the fire would hit the corresponding settlement. An example is shown in Figure 6. The simulations allowed the fire management authorities to understand the challenge they may be called to face under such fire scenarios. Additionally, they helped to illustrate to the people of the particular settlements that there can be conditions under which, within a short time, the firefighting resources of the island will be overwhelmed and will not be able to control the blaze or defend all the houses. This made many people take the fire prevention messages more seriously and realize that they need to prepare their homes for such an event.

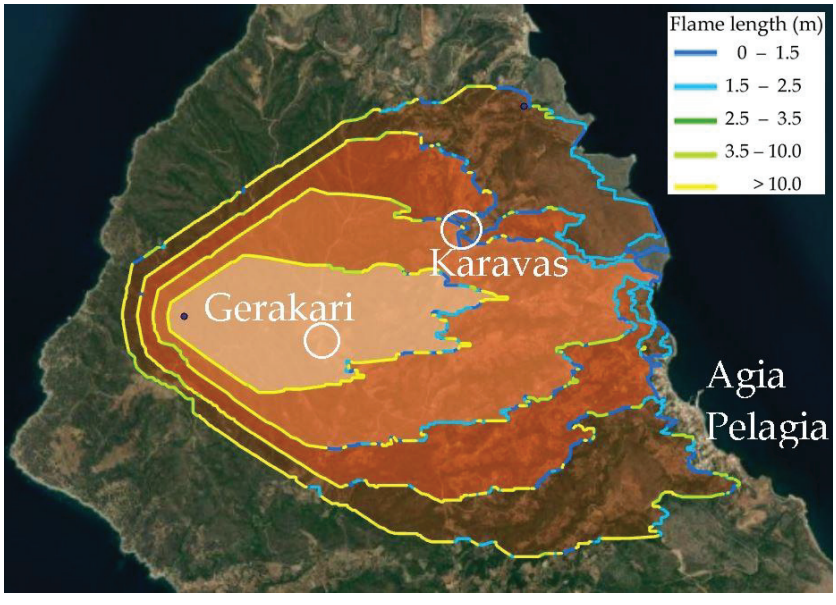


Figure 6. A fire spread simulation example, using the G-FMIS fire simulation system, in the north part of Kythira (Karavas and Gerakari settlement) under a west wind, showing fire perimeter growth (in four hourly steps) and flame length (m) along the perimeter color-coded in five classes.

3.5. Assessment of the Risk of Destruction of Structures with the Help of Volunteers

The work of the volunteers on assessment of the risk of destruction of each structure in the three settlements (Figure 7) resulted in 704 completed forms. Finally, 610 structures were evaluated. The remaining 94 were abandoned or collapsing, or, in a few cases, there were missing data in the forms. The evaluation of the risk of each structure through a scoring system was further reviewed, adjusted and verified in the field by the fire experts of the two partners. Subsequently, a form was prepared for each structure to be delivered to the homeowners. This semi-automatically created form included an assessment of destruction risk in cases of fire but also offered guidance on needed safety improvements and suggestions on how to react in cases of fire (Figure 8).

Figure 7. A team of volunteers filling risk assessment data forms for homes in one of the settlements in Kythira.

Προστασία της Φύσης
ΕΛΛΗΝΙΚΗ ΕΤΑΙΡΙΑ ΠΡΟΣΤΑΣΙΑΣ ΤΗΣ ΦΥΣΗΣ

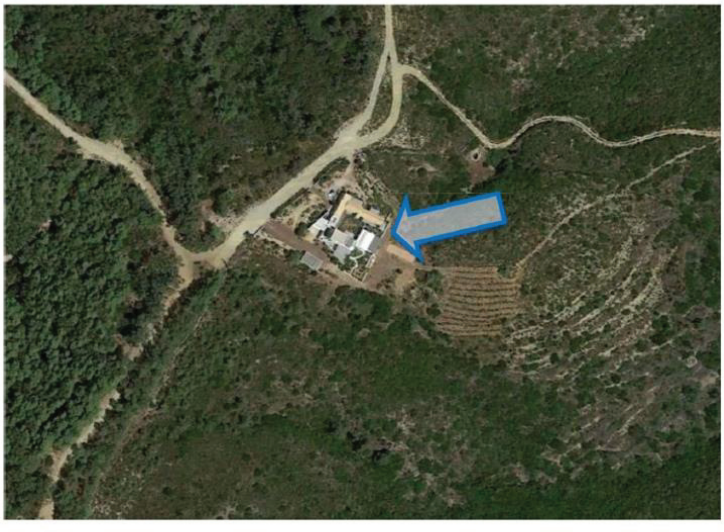
Ινστιτούτο Μεσογειακών Δασικών Οικοσυστημάτων

ΠΡΑΣΙΝΟ ΤΑΜΕΙΟ

Έργο: «Καινοτόμα δράση για την πρόληψη των δασικών πυρκαγιών στα Κύθηρα με την κινητοποίηση και συνεργασία του πληθυσμού, πιλοτικά σε 3 οικισμούς» ΜΕΤΡΟ: «ΚΑΙΝΟΤΟΜΕΣ ΔΡΑΣΕΙΣ ΜΕ ΤΟΥΣ ΠΟΛΙΤΕΣ», ΧΡΗΜΑΤΟΔΟΤΙΚΟ ΠΡΟΓΡΑΜΜΑ: «ΦΥΣΙΚΟ ΠΕΡΙΒΑΛΛΟΝ & ΚΑΙΝΟΤΟΜΕΣ ΠΕΡΙΒΑΛΛΟΝΤΙΚΕΣ ΔΡΑΣΕΙΣ 2018»

Evaluation of the risk of destruction of a house due to a forest fire

House - Questionnaire Number:	XXX
Owner:	Unknown
Housing Location:	Gerakari
Phone number:	Unknown



Index A- Hazard resulting from the characteristics of the forest fire	Very High
Index T - Vulnerability of the residence	Average
Index K – Integrated risk assessment for the structure	**High**

Figure 8. *Cont.*

The risk of destruction of the house by a forest fire is High.

The surrounding vegetation is a factor of especially high risk to your house. You should contact the local Forest Service or the Municipality immediately in order to get help regarding prevention measures you could take. You have to clean the area around the house from dead burnable material to mitigate the danger from a possible forest fire. Grasses have to be cut and removed, shrubs must be thinned out and lower tree branches have to be pruned to a minimum of 2 meters from the ground.

The vulnerability of your residence from a probable forest fire is average. There are some changes and improvements that should be made to the most vulnerable elements, which are a source of weakness. To keep the safety of your residence at a high level, make sure that in the case of a forest fire you will shut off the windows and doors in time, to prevent smoke and burning embers from entering. If you cannot evacuate in time, in an organized way and safely, you will need to remain in the house so that you will not be exposed to smoke and flames.

You should know that if you decide to stay and protect your residence, you should have received training by the Fire Service and should be using the proper equipment for personal protection and firefighting.

If there are obstructions to the access of the firefighting forces to your home, they may delay their efforts and decrease their ability to fight the fire.

A wooden pergola can be an element that increases the risk in case of a forest fire, especially if combined with straw, water reed or cloth to provide more shade. To decrease the risk, you may paint it with fire-resistant varnish, and may use a fire-resistant cloth.

Fences made with coniferous vegetation (Thuja, Leyland, Cypress) are easy to ignite even from lighted embers and burn with great intensity. Fences made with broad leaved plants (such as *Nerium oleander*) and even better with climbing species (ivy, honeysuckle) offer protection instead, especially if they are watered regularly.

The above assessment is a short and non-exhaustive way of assessing the potential risk of destruction of a house by a forest fire. The method of calculation covers the most important factors of this risk and gives a fairly representative assessment, in order to offer a first assessment to the owner as to whether his home is in danger and what could be the possible changes to improve the situation. By using the corresponding application on the IMFE website (http://www.fria.gr/prolipsi/files/Assessment-Form.html) the result of possible changes that the owner will make in reducing the risk can be evaluated.

ATTENTION: As IMFE, is not directly involved in the recording of data, but also due to the existence of many unpredictable parameters during the passage of a fire, IMFE cannot be held responsible for any failures. Citizens should be informed and follow the instructions of the official bodies in case of fire. More information on fire prevention for citizens is available at: http://www.fria.gr/prolipsi/, and about the project at https://tinyurl.com/kainotoma-kythira

Figure 8. An example of the form with assessment of the risk of a particular house, to be handed personally to its owner.

In addition to the assessment of individual structures for the benefit of the owners, the results were also shown on a map that was made available (confidentially) to the authorities (Figure 9). The combination of fire behavior analysis with the structure vulnerability map allows better protection of the settlements both at the fire prevention planning stage and when trying to defend them in case of fire.

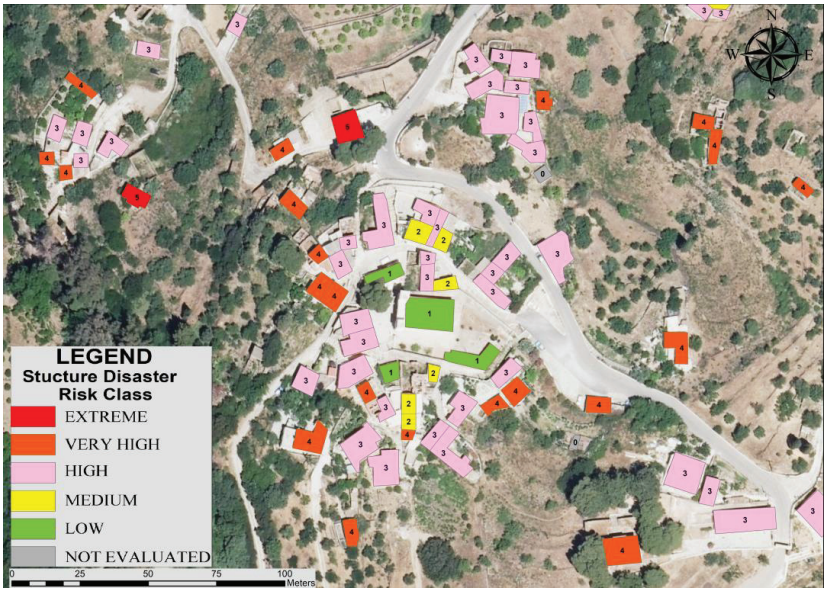


Figure 9. A small example of the structure disaster risk map that was created for use by the authorities at Kythira island. Each structure is color-coded in one of five risk classes (low to extreme).

3.6. Owner Opinion about Their Home's Assessment and Their Willingness to Act

The homeowners, who received the forms about the fire risk of their structures, were asked through a short questionnaire to state their opinion about the assessment they received and to express their willingness to act to improve the safety of their structure. A few more questions of interest were also asked. This follow-up was also carried out by volunteers. A total of 230 valid questionnaires were collected.

The questionnaire results showed that the fire of 2017 had changed the viewpoint of many homeowners regarding the potential risk the fires represent for their home. Before the fire, 23% declared that they did not perceive any threat, while 25% were slightly worried. After the fire, the corresponding percentages dropped to 8% and 14%, respectively. The majority of the homeowners (71%) declared that they had not attended any of the educational activities of the project, providing a feeling about the reach of the project to the people on the island.

The perception the homeowners had about the potential fire risk for their home before they received the form, proved to be quite different than the assessment they received (Figure 10). However, they agreed overwhelmingly with the assessment after studying the form (Figure 11). Furthermore, the majority of them stated that they will implement the suggestions in the form completely (48%) or partially (38%) (Figure 12).

3.7. Map of Firefighter Safe Separation Distance (SSD)

Using vegetation height, slope and wind as input variables, the firefighter safe separation distance [57,58] was calculated and mapped using ArcGIS (Figure 13). The map reveals areas, mainly in the north of Kythira, where ground firefighting of the fire front would be impossible in case of a fully developed summer fire and can contribute greatly in presuppression planning.

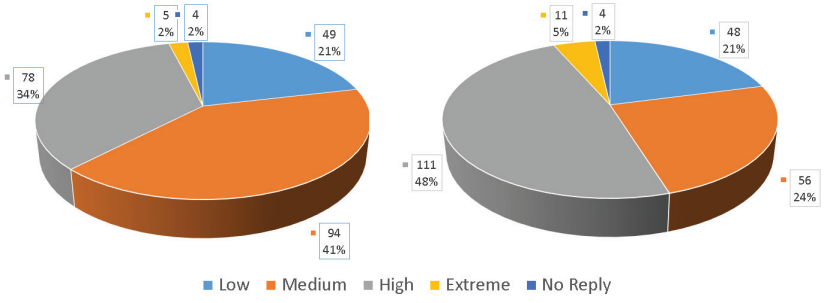


Figure 10. Perception of the homeowners of the potential risk for their home in case of forest fire before they received the form (**left**), and the risk assessment through the form (**right**).

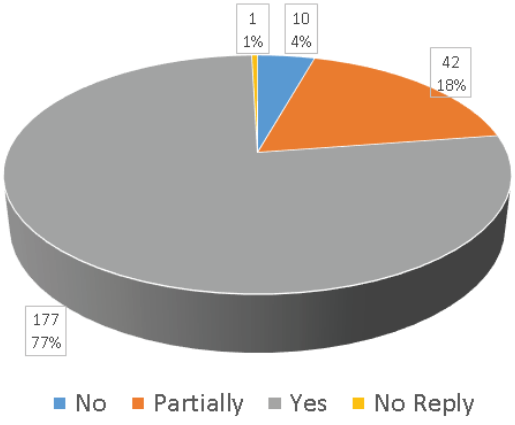


Figure 11. Degree of agreement of the homeowners with the assessment they received about the risk to their home in case of fire.

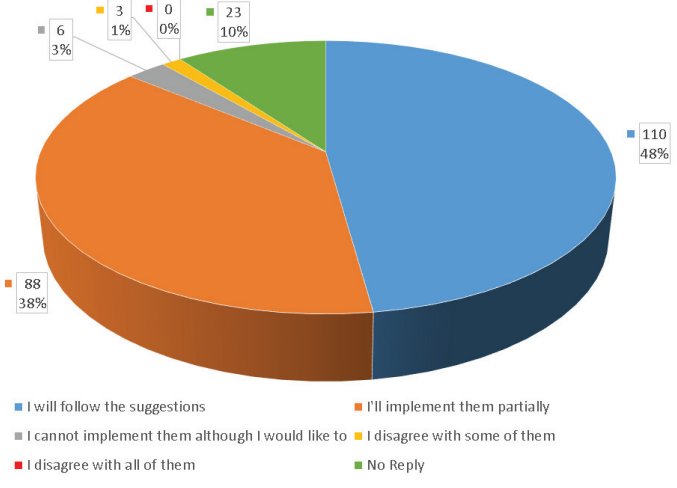


Figure 12. Stated willingness of homeowners to implement risk mitigation measures for their homes, according to the suggestions provided to them through the risk assessment forms.

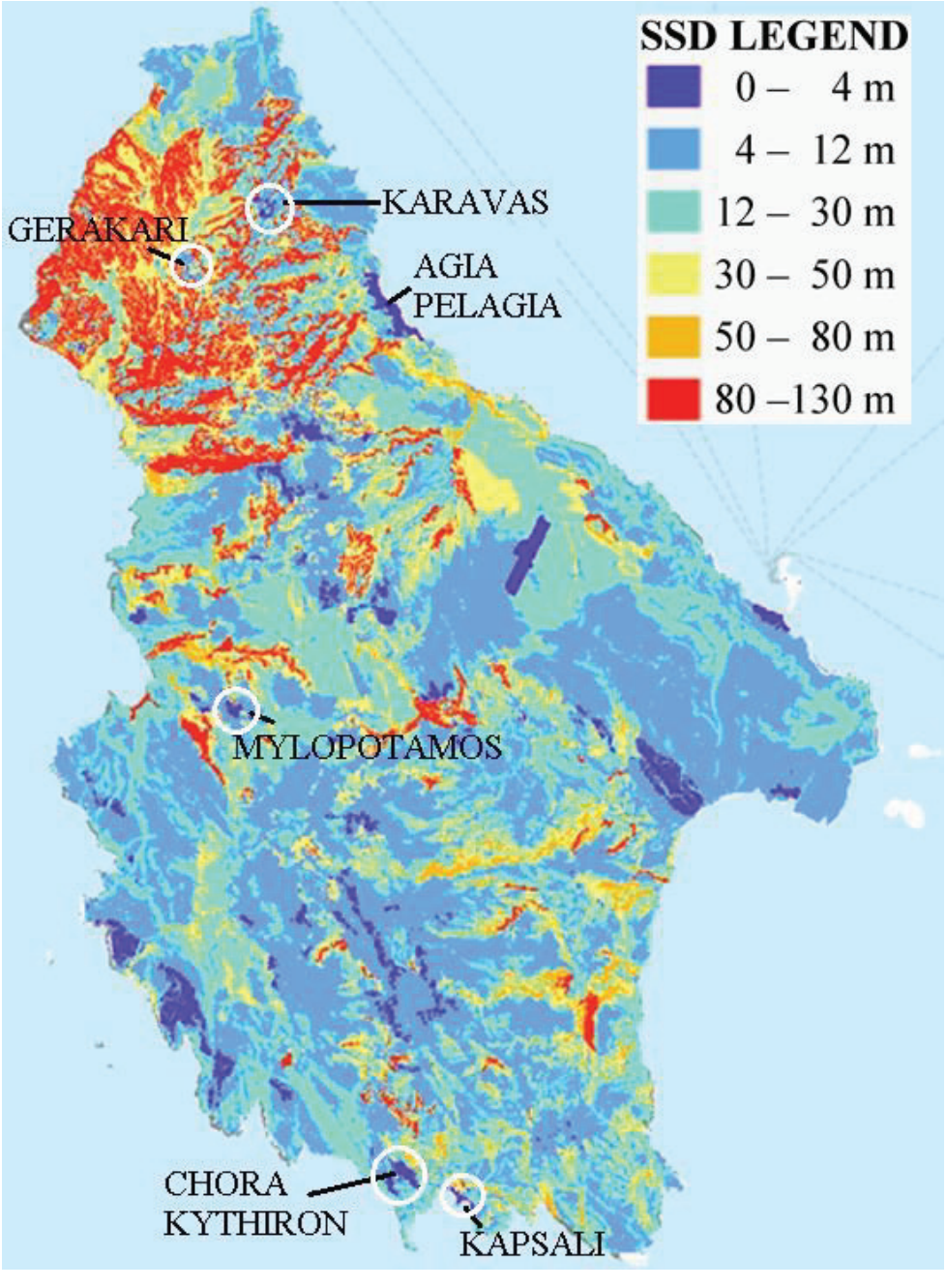


Figure 13. The firefighter safe separation distance (SSD) in meters mapped across Kythira in six classes.

Focusing on the settlements under consideration and combining the SSD map, the house risk assessments and the ease of access, the areas of great concern where there can

be grave danger to the people in case of fire became evident. These were pointed out in detailed maps that were provided to the authorities (Figure 14).

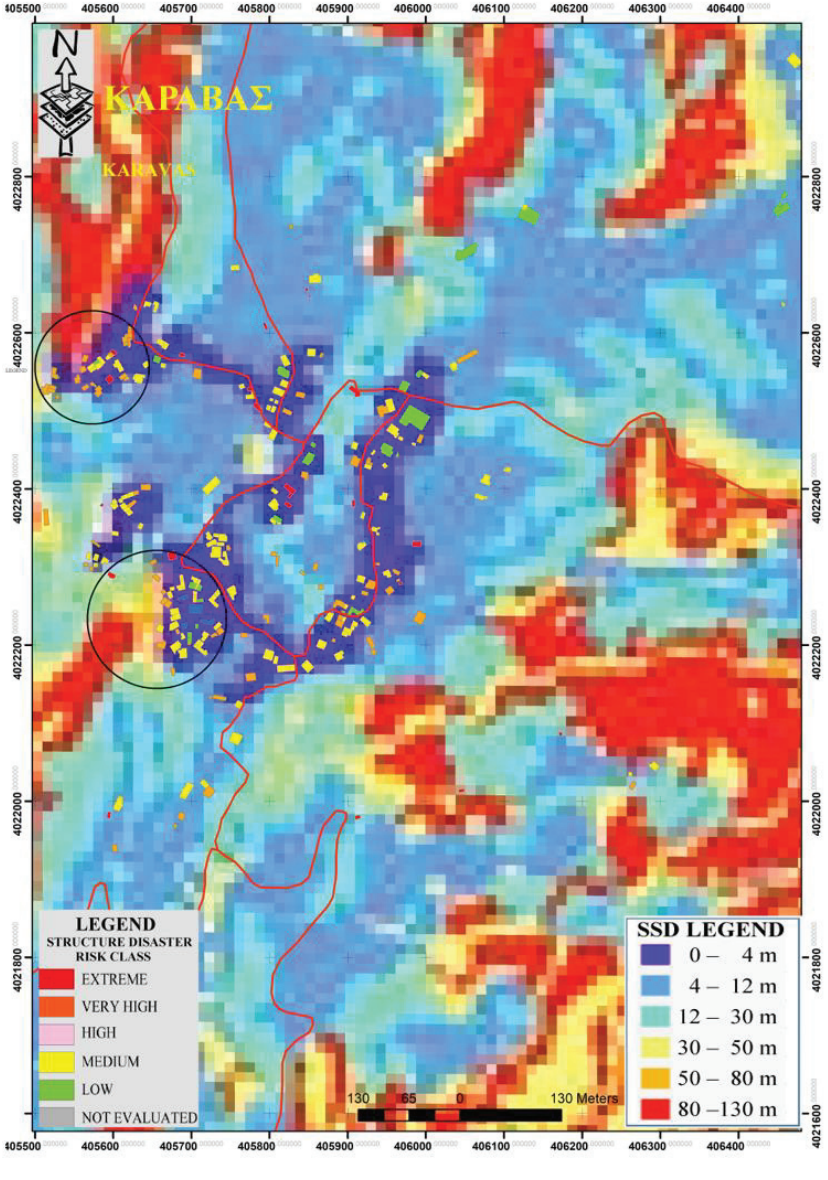


Figure 14. A detailed map of homes in Karavas, color coded according to their risk class, and the SSD in the vicinity of the settlement. Two groups of homes that can be at extreme risk in case of a fire arriving from the west, are indicated with black circles.

3.8. Mobilization and Cooperation of the Population

Early in the timeline of the project it was deemed necessary to explain to the population the concept and breadth of fire prevention and its importance for the island of Kythira. After initial contacts it became clear that there had to be separate workshops organized in

the north, center and south of the island, because people would not be willing to travel. Thus, it was decided to carry the workshops in small places that they felt comfortable with (Figure 15). The first round of workshops that consisted of talks on fire prevention followed by discussion achieved its objective because it stirred interest and permitted the formation of teams of volunteers. Based on the realization that an intense quick-spreading fire under high fire danger could easily overwhelm the limited firefighting resources of the island, exposing settlements to risk of destruction before the arrival of reinforcements, it was demonstrated that improvement of the safety of homes had to be one of the priorities. Thus, it was agreed with the volunteers that one of their main contributions could be to help assess the risk of destruction of individual homes in the three settlements, a task they successfully completed as explained earlier.

Figure 15. Examples of two workshops in a tavern in Mylopotamos (**left**) and in a small gallery in Chora Kythiron (**right**), in 2019.

Additional meetings were carried out later in the life of the project to act as refreshers of the key prevention messages and as opportunities for information dissemination on the overall progress. However, with the onset of the COVID-19 pandemic in March 2020, the task became much more challenging. There were periods of many months during which it was not possible to travel to Kythira, and when this was allowed, the meetings had to be carried out in open spaces such as a village square, a restaurant or even an open-space bar (Figure 16). Additionally, many people who would normally come to Kythira in the summer (e.g., Kythirians who emigrated abroad many years ago but maintain a home on the island, or those who live in Athens) were not able to make it in the summer of 2020. These difficulties made it necessary to extend the project by 1 year, to the end of September 2021, in order to carry out activities in the summer of 2021.

Figure 16. Examples of two workshops in open spaces, in 2021.

In parallel to the workshops for the grown-ups, talks to the students of the only high school on the island and the two elementary schools aimed to convey the message of fire prevention to the new generation. The talks to the high school students were delivered by the fire experts of the partners and were followed by discussions. On the other hand, specialized environmental educators of the HSPN, employing not only talks but also interactive games in the schoolyard, delivered the message to the younger pupils

(Figure 17). These activities were particularly successful as these young people, having witnessed the disastrous fire of 2017, were more than eager to pick-up the fire prevention message and to spread the word. They were also given fire prevention leaflets to carry home, which they were happy to do.

Figure 17. Examples of talks to high-school students (**left**) and activities in the schoolyard with pupils (**right**).

The pool of volunteers and of enthusiastic students was also given the opportunity to act in the frame of forest fire prevention and post-fire rehabilitation participating in two activities organized mainly through the efforts of HSPN. The adults treated understory fuels in a *Pinus halepensis* stand along a highly used road, while the students worked on reforestation in a burned area (Figure 18).

Figure 18. Two of the activities that aimed to foster voluntary spirit; fuel treatment (**left**) and reforestation (**right**).

Regarding dissemination of prevention messages at massive scale, the teams of the two partners prepared a four-page brochure that was distributed to the population at the start of the fire season of 2021. Additionally, they prepared two informative fire prevention videos which were uploaded to YouTube at the following links: (a) Making a home safe for the case of a forest fire (https://youtu.be/HmZx1yWtuYI, accessed on 1 December 2021), and (b) How to react in case of fire (https://youtu.be/zS5JN8Kd48A, accessed on 1 December 2021). Following uploading, the links were publicized through various channels (mailing lists of professionals, relevant internet sites, social media, etc.).

The four-page fire prevention brochure that was produced specifically for Kythira was received very positively during the meetings held in June 2021, resulting in the need for a second printing. However, at that time, the local entrepreneurs also suggested that there is a need for creation of a similar brochure in foreign languages, to be distributed through hotel owners and other professionals to the numerous tourists visiting the island every summer.

4. Discussion

All the activities described earlier have certainly contributed towards the main objective of the project, to improve forest fire prevention in Kythira. This, rather than introduction of technical advancements in fuel mapping or fire modelling, was the emphasis of the work. The element of innovation was mostly in the way the technical work blended with the involvement of the people in order to achieve better fire prevention efficiently. Working

with the citizens on fire prevention, of course, is not new. There exist numerous efforts around the world, such as the FIREWISE USA program of NFPA, which has a long history, recognizes the value of voluntary action and provides numerous resources to people in order to make their communities and homes safe from wildfire [35]. Community participation is sought and is a longstanding practice, not only in the USA, but also in Canada and in Australia [32,36]. However, people's attitudes are very different between countries and continents and the same is true for their social structures and their natural and built environment [59,60]. For example, while in Greece less than 10% of adults participate in volunteer activities, in the European Union, in countries such as The Netherlands, Sweden and Austria this percentage is over 40% [61]. As a result, the examples of community involvement cannot be simply copied.

In Greece, organized volunteerism historically has not been strong, while people are very eager to help on a personal basis when the need arises, if they are motivated appropriately. In Kythira, motivation was tried, innovatively, with the involvement and cooperation of volunteers with the fire experts, and their ultimate contribution to fire prevention planning on the island, putting an emphasis on the idea of providing examples. As the other people watched the volunteer teams become organized and trained, and then visit structures in the three settlements completing forms, they became curious. Participation in the talks and the activities increased. Many owners of restaurants and coffee shops offered their space and infrastructure for free, initially indoors, and after the onset of the COVID-19 epidemic, in the space outside their shops, providing a further positive example. The elementary and high-school teachers on the island also contributed enthusiastically, facilitating the work of the environmental educators of the HSPN. The delivery of the risk assessment forms by the volunteers to the structure owners, on a personal basis, further increased awareness and provided motivation by example. The percentages of agreement regarding the risk evaluation of the homes and the willingness to take measures for home risk mitigation were quite high and impressed the researchers who did not expect this from the aging and generally laid-back population of the island. The result is in line with the findings of McFarlane et al. [62] that threat assessment has the greatest effect on mitigation by homeowners, followed by perceived effectiveness of mitigation. The risk assessment forms that were given personally to the homeowners in Kithira offered both these elements.

It is worth noting that the change in the perception of homeowners regarding the risk to their homes and their willingness to act is not independent of the large 2017 fire that they experienced and is in line with the findings of [63]. Actually, the project made use of the "window of opportunity", regarding population mobilization after a disastrous wildfire, that was reported by McGee et al. [63]. The impression made by the 2017 fire was even stronger and longer-lasting for the pupils and students. Even in 2021, four years later, the memory persisted and the attention of the students to the prevention messages remained very high.

Community engagement and participation, as a rule, is initiated and managed by official agencies [36]. In Greece, with some notable exceptions, this approach has not worked well so far. The alternative developed in this study provides an effective approach, which is tailored to the profile and mentality of the population. The interaction of experts with the citizens, the two-way communication, and the feeling that they were all participants in a common effort were keys to success. On the other hand, a sophisticated approach based on volunteered geographic information (VGI), using social media and technologies such as web-based mapping, as tried in [36], would likely be unsuccessful in Kythira.

The technical information offered to the authorities, including fire occurrence analysis, forest fuel mapping, fire spread simulations, and fire damage potential (both from the side of the fire and the vulnerability of structures), can help greatly regarding fire prevention planning and setting fire suppression priorities. On the other hand, all the activities with the citizens, with the addition of articles, videos, and local radio interviews, make it likely that a significant percentage of the population of Kythira has been exposed to the concept and have learned about the practicalities of forest fire prevention.

Assessment of the effectiveness of the activities of the project on the outcomes of fire prevention, especially as manifested by burned area, the occurrence of a large fire, or fire caused damage, cannot be done with confidence in a short period of time. Nevertheless, there were four fires recorded in 2019 and nine fires in 2020. These numbers are lower than the 11.5 fires that occur on average per year. Furthermore, the total burned area was 16.1 ha in 2019, and 25.5 ha in 2020, which is much lower than the average yearly burned area of 306.8 ha for the 2000–2019 period. Also, there were no reported injuries to people or damage to homes.

As seen in the fire statistics of the island, large fire events happen sporadically, usually in fire seasons that are difficult for the whole country. This may reflect the high fire danger conditions that lead to aggressive fires starting, which quickly exceed the local firefighting capacity. It may also reflect the arrival of reinforcements, which may initially be relatively weak and may come with some delay due to the overall demand for resources in the country. This parameter cannot be influenced decisively by the fire prevention efforts on the island.

Further to the above, on a short time scale, the occurrence of a large fire is to a large extent a matter of coincidence. For example, many fires with very intense fire behavior, thanks to the prevailing wind, quickly reach the sea. On the other hand, an unexpected event, such as the mechanical failure of the first fire truck that was dispatched for initial attack to the fire of 4 August 2017, may lead to a disaster.

The difficulty of assessing the effectiveness of fire prevention in a short period of time is well-known and is probably one of the reasons governments and state agencies tend to neglect prevention and favor investments in fire suppression, which, in the short term, has more tangible results. Thus, in the case of Kythira, the satisfaction expressed by the firefighting authorities on the island, and the consideration of project findings in planning for the 2021 fire season, can be considered as positive signs.

The activities of fuel management and reforestation in the frame of the project have been to relatively limited extent of operational significance. However, the results stand as an example for the people on the island, have offered satisfaction, and have improved the community spirit of the participants. It is worth noting that in later meetings with the students they asked eagerly when such an activity will be repeated. It is quite likely that among them will be the future volunteers of the island.

On the negative side, there were a few people among the local authorities who remained negative about the whole effort. This could not be easily explained but may be the outcome of not understanding the broadness of the field of fire prevention, which does not simply include (often costly) technical measures, such as road maintenance, water sources, etc. It could also be a personality issue, as some people in power want to control everything.

Finally, it should be mentioned that although there are people on the island who were very concerned about its environment and its fire safety, especially after the 2017 fire, no initiative, such as that discussed here, was started spontaneously by them. They were happy to volunteer when the opportunity came, and devoted a significant amount of time, but there was always the need for scientific and technical guidance and cooperation from the two project partners. The gap caused by the measures for the COVID-19 epidemic resulted in minimization of activities, especially throughout 2020. Nevertheless, all those involved showed the necessary flexibility, including the funding agency which agreed to two deadline extensions.

5. Conclusions

It cannot be predicted with certainty what will happen on Kythira in the years after the end of the project, regarding continuation of the activities. There is an effort to establish a permanent network between the volunteers, supported as much as possible by the project partners (an environmental NGO and a state research institute), both with a long-term interest and commitment, as their will to contribute is not strictly limited by the existence

of a budget. They will try to obtain some further funding for the future to continue the work in Kythira and in similar places.

Concluding, it should be mentioned that projects of this kind are not easy to plan and carry out over large spatial scales. It is advisable that large prevention programmes (e.g., country level) should have certain guiding axes, common approaches, and supporting materials, but should also try to consider the local characteristics and to address the people locally. This can increase both effectiveness and efficiency. The lesson that has been learnt through the work described here is that a small yearly investment in fire prevention, assigning/employing highly motivated specialized individuals, with a small budget, to organize fire prevention activities such as those described above, can make a substantial long-term contribution to reducing fire loads and damage. This cost could be less per year than 3–4 h of flight time of aerial resources and the results could be tremendous. Furthermore, if a fire prevention network is developed (e.g., across Greece) to link, guide and support these individuals, monitoring and assessing the results, any weaknesses would be quickly resolved and the outcome would be impressive.

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Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable. The participating volunteers and other citizens remain anonymous.

Data Availability Statement: Publicly available datasets on forest fires in Greece were analyzed in this study. This data can be found here: https://www.fireservice.gr/el_GR/synola-dedomenon, accessed on 1 December 2021. The data presented in this study regarding house risk assessment and the questionnaire to the home-owners are available on request from the corresponding author. The data are not publicly available due to privacy reasons.

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Building Resilience to Natural Hazards at a Local Level in Germany—Research Note on Dealing with Tensions at the Interface of Science and Practice

Gérard Hutter *, Alfred Olfert, Marco Neubert and Regine Ortlepp

Research Area Built Environment—Resources and Environmental Risks, Leibniz-Institute of Ecological Urban and Regional Development (IOER), Weberplatz 1, 01217 Dresden, Germany; a.olfert@ioer.de (A.O.); m.neubert@ioer.de (M.N.); r.ortlepp@ioer.de (R.O.)

* Correspondence: g.hutter@ioer.de; Tel.: +49-351-4679-283

Abstract: Building resilience is a core element of urban resilience that refers to both the (1) intended physical change of the building stock and the related blue, green, and grey infrastructure, as well as (2) the social process of increasing resilience through the goal-driven cooperation of scientists and practitioners. Building resilience at the interface of science and practice is characterized by tensions and a range of approaches to dealing with tensions. To specify this proposition, this research note adopts a strategic spatial planning perspective and introduces the typology of "motors of change" from organizational and management research. We focus on a goal-driven motor of change ("teleology") and highlight three approaches to dealing with tensions: developing a strategic focus of knowledge integration, setting priorities to enhance resilience as a pro-active ability of disaster risk reduction (DRR), and compromising in the management of trade-offs, such as those between the scales of resilience. For the purpose of illustration, this research note refers to examples of building resilience at a local level in Germany, dealing with heat stress in urban areas, managing the risk of extreme flood events, and analyzing the resilience of innovative infrastructure solutions.

Keywords: compromise; disaster risk reduction (DRR); motor of change; setting priorities; strategic focus; teleology

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1. Introduction

The decade from 2011 to 2020 was the "hottest" in history and the average global temperature by 2020 had risen by 1.2 °C since the start of the industrial era [1]. With extreme weather events becoming more frequent and the negative impacts of climate change intensifying, the need to enhance resilience seems to be clear. Around the globe, resilience has become the hope for many that cities and regions are increasingly capable of dealing with risks and uncertainties related to hazards in the context of climate change, especially extreme events and their potentially disastrous consequences (e.g., [2–7]).

Some scholars argue that the high diversity of resilience understandings provides the term with something of "poor scientific status" [8] (p. 15) or, even worse, something that is "vulnerable" to ideology-driven misuse and over-biased policy making (e.g., neoliberal policies of allocating responsibility to private actors, but *not* sufficient resources [2]). However, we suppose that the term "resilience" has some merit, if the multiplicity of meanings of the word is taken into due account [9] and if we consider the "messy history" [10] of the term. Meerow and colleagues [3] dealt with the messy history of resilience, especially urban resilience, and provided a definition as a starting point for our argument:

> *"Urban Resilience refers to the ability of an urban system—and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales—to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity"* [3] (p. 45).

We understand building resilience as a core element of urban resilience that refers to both the intended *physical* change of the building stock and the related blue, green, and grey infrastructure, as well as the *social process of increasing resilience through the goal-driven cooperation of scientists and practitioners*. Hence, building resilience is related to all four subsystems of urban resilience mentioned by Meerow and colleagues [3] (p. 45): urban form and infrastructure, networked material and energy flows, socio-economic dynamics, and governance networks.

Meerow and colleagues argue that scholars and practitioners need to address *tensions* in urban resilience [3] (p. 45). There are conceptual tensions, as well as tensions that specifically arise at the interface of science and practice, for translating the concept of resilience into an "implemented reality" in cities and regions. The consideration of tensions is also important to accomplish disaster risk reduction (DRR). For instance, DRR is rooted in general risk management concepts (e.g., acceptable risk, risk reduction plans [11,12]). The ideal type of risk management cycle of prevention, mitigation, preparedness, response, recovery, and rehabilitation emphasizes *anticipation and planning*. In contrast, there are resilience scholars who underline the limitations of effective planning in an uncertain world and who argue not to underestimate the need for *reactive* management [13]. Hence, if we address issues of building resilience and DRR, we should not omit tensions.

On a highly abstract level of argumentation, tension stands in contrast to incoherence and harmony. In the case of incoherence, elements of social relations and individual actions are *not* related. In the case of harmony, elements fit together without tensions like conflicts and dissonance. On a more specific level, tension is an umbrella term that covers different *kinds* of tensions (e.g., conflict, dilemma, dissonance, duality, paradox, and trade-off).

In this research note, we argue that tension is useful as an umbrella term, if multiple kinds of tensions and ways of dealing with them are considered (and not only through referring to different contents and context conditions of tensions). The overall research proposition is as follows: *Translating the concept of building resilience into practice is characterized by a multitude of tensions, and framing these as tensions of different kinds is crucial to analyze the effectiveness of dealing with such tensions.*

For instance, trying to negotiate compromise in the case of the diverging mindsets of people, with regard to the limitations of planning in an uncertain world, may be an ineffective way of dealing with this type of tension. Dealing with diverging mindsets often requires the justification of priorities, in order to regulate which mindset is more important in which situation and the reasons for this.

The purpose of this paper is to provide a conceptual, mainly descriptive, and process-oriented contribution to the research that deals with tensions at the interface of science and practice, especially in the form of collaborative projects between scientists and practitioners. Three comments on this purpose and how we accomplish it are in the following order:

(1) We label our contribution as a *research note*, because we expect that the note may be helpful as a conceptual input into more ambitious future research contributions (such as providing an extensive literature review of tensions in building resilience to natural hazards, conducting intensive comparative case study work to elaborate on causal research propositions, or testing specific hypotheses through the quantitative analysis of many cases [14,15]).

(2) To accomplish this purpose, we qualitatively analyzed a broad range of scientific publications covering conceptual, theoretical, and empirical contributions to the research. To achieve this, we used categories of strategic spatial planning [16–19]. We also referred to the *process-oriented* typology of "motors of change" as suggested by Andrew Van de Ven and Marshall Scott Poole [20,21] in organizational and management research. This helped to clarify the focus of the research note on the goal-driven processes of building resilience (teleology in contrast to social change as dialectical change, life-cycle change, or evolution). We "derived" three process patterns that are illustrated by results from our own completed empirical research projects (see [6] for a summary): developing a strategic focus, setting priorities, and negotiating compromise. The three project examples address

different contents of resilience building at a local level: dealing with heat stress and heat waves; managing flood risk, especially the risk of extreme flood events; and infrastructure resilience. In summary, this paper is the result of desktop research on a conceptual level based on our own previous empirical work.

(3) This research note seeks to address a specific and important *research gap*: dealing with tensions of building resilience at a local level and at the interface of science and practice requires "true" process-oriented research [22]. Even if there are many research contributions that address issues of dealing with tensions in resilience building, for instance [2,4,23], *process* research on building resilience through managing tensions still needs to be enhanced [6,24–27]. A strategic spatial planning perspective, as well as the typology of "motors of change", is an ideal goal for this research purpose.

The following is structured into two main sections. Section 2 presents the framework of our conceptual argumentation (strategic spatial planning, motors of change, especially goal-driven processes, and three process patterns of building resilience at local level and at the interface of science and practice: developing a strategic focus, setting priorities, negotiating compromise). Section 3 conceptually elaborates on the three process patterns of dealing with tensions, not least through referring to project examples of building resilience at a local level in Germany. Section 4 concludes the research note.

2. Strategic Spatial Planning in Projects at the Interface of Science and Practice

There are many different perspectives to approach the topic of building resilience to natural hazards at the interface of science and practice [28,29]. This research note is based on a strategic spatial planning perspective. Hence, we need to clarify what characterizes this perspective and how this relates to our topic. For our work, we adopt the widely acknowledged understanding of strategic planning proposed by Louis Albrechts:

> *"Strategic planning is selective and oriented to issues that really matter. As it is impossible to do everything that needs to be done, "strategic" implies that some decisions and actions are considered more important than others and that much of the process lies in making the tough decisions about what is most important for the purpose of producing fair, structural responses to problems, challenges, aspirations, and diversity."* [19] (pp. 751–752).

Planning scholars, such as Louis Albrechts and Patsy Healey, underline that strategic *spatial* planning should not be confounded with strategic planning *in business organizations*. Three reasons for this are especially noteworthy. Firstly, strategic spatial planning encompasses categories of spatiality at the core of strategy-making (e.g., spatial levels, node, territory, location). Secondly, this approach to planning is less characterized by analytical procedures, as in case of business organizations, and more by situational and value-laden decisions on how to make "the tough decisions about what is most important" [19] (p. 752). Thirdly, all three dimensions of strategic spatial planning—content, process, and context—are, in principle, equally relevant to accomplish planning efforts [17,18]. *This research note emphasizes the processual dimension of spatial strategy making in cities and regions.*

2.1. The Processual Dimension of Strategic Spatial Planning and the Focus of the Research Note

Based on deep theoretical and case study work, Patsy Healey provides a summary account of process patterns of strategic spatial planning. According to Healey [16], four processes characterize strategic spatial planning: scoping the situation, mobilizing attention *for change* in cities and regions, enlarging the "intelligence" of collective action (for instance, through new expert knowledge and the consideration of lay knowledge), as well as creating frames for collective action and selecting actions (e.g., joint projects at the interface of science and practice).

This research note focuses on how actors involved in building resilience *create frames and select actions*. Frames provide a direction in collective action. Action with tangible outcomes is important to facilitate a trust-based cooperation between actors with different perceptions, mindsets, and interests. Creating frames and selecting actions are necessary

activities of strategic spatial planning [30] and are often characterized by tensions. The deliberation on options of dealing with tensions is a necessary condition of *successful* strategic spatial planning [17,18].

However, the conceptual element of "creating frames, selecting actions" remains rather abstract. Therefore, the following section specifies this element as a *goal-driven process of social change* in contrast to other types of social change (teleology in contrast to dialectics, evolution, and life-cycle change [20,21]). Social change and strategic spatial planning are closely related, because the latter is commonly understood as "transformative governance work" [16] (p. 440).

Subsequently, we further differentiate the notion of a goal-driven process in three more specific process patterns at the interface of science and practice in the form of a project: (1) developing a strategic focus of collective action, especially with regard to tensions in knowledge integration; (2) setting a priority on building resilience and DRR as *pro-active* ability; and (3) negotiating compromise, if managing trade-offs is possible. We use project examples from our own recent empirical research in Dresden/the Free State of Saxony/Germany to illustrate these three process patterns (Table 1).

Table 1. Research focus on building resilience as a goal-driven process of social change and three process patterns that are illustrated through project examples at a local level in Germany.

Building Resilience as Goal-Driven Process	Illustration of Creating Frames and Selecting Actions through Project Examples at the Interface of Science and Practice
Developing strategic focus	The project example "HeatResilientCity" (HRC) in Dresden-Gorbitz illustrates tensions in knowledge integration at the interface of science and practice. Strategic focus on the common topic of dealing with heat stress and heat waves in urban areas facilitated an agreement between scientists and practitioners of which local measures to analyze and actually implement in the "real world".
Setting Priorities	The project example in Brockwitz/City of Coswig nearby the City of Dresden illustrates how to justify setting a priority on building resilience to *pro-actively* reduce disaster risk, for instance, through analyzing structural alternatives (dike construction vs. house lifting) to reduce the risk of extreme flood events and through using tools for visualizing the results of such analysis.
Negotiating compromise	The project example TRAFIS on creating a "sustainability check" illustrates that negotiating compromise is not only important to manage conflicts between interests, but also to manage trade-offs in analyzing the complexity of urban resilience to natural hazards (perturbations of infrastructure systems as part of urban systems).

Source: Project examples from our own empirical research (see [6] for a summary of contents and methods, see below Section 3 for how project examples are used to illustrate the three process patterns, and the acknowledgements for formal information).

2.2. Dealing with Tensions in Goal-Driven Processes of Change

Similar to strategic spatial planning, social change is also closely related to issues of building resilience. Currently, the challenges of urban transformation in developing sustainable solutions for pressing problems (such as, for instance, the potentially disastrous consequences of climate change in cities and regions) seem to reach the center stage of debates on urban resilience. Building resilience entails the vision of a better future through more resilient cities and regions. DRR entails the vision of a better future in which less disaster risk exists. Hence, both imply the imagination of a different future in relation to the present conditions.

In more general terms, change can be defined as a difference in properties (or attributes) of a focal unit (e.g., person, organization, network, urban system) over time, measured at a minimum at two time points. There is an abundance of concepts and theories to

specify the focal unit, its properties, change as difference over time, as well as how and why change occurs. Under which conditions change is amenable to intentional change is also an important question [20,21].

Against this background, the following is based on two assumptions: (1) To conceptualize building resilience as social change in line with strategic spatial planning, it is useful to adopt the theoretical framework developed by Van de Ven and Poole [20,21] in organizational and management research. (2) This framework has not yet been adopted intensively to issues of building resilience.

Van de Ven and Poole [20] ground their theoretical framework to analyze social change in an extensive review of diverse literature. In order to analyze not only why this change occurs, but also *how* the process of change unfolds, they identify four "Families of Ideal-Type Theories of Social Change" [20] (p. 514). They label these families as "motors of change". Two of those motors are of special interest:

- *Teleology:* The key metaphors here are "purposeful cooperation" and "planned change". Social change is driven by a desired future in the sense of an envisioned end state ("goal"). Statements on goals do not only legitimize collective action; they actually motivate and guide the involved actors to initiate and implement change. There is a high consensus between the involved actors on the envisioned end state and on means that are judged to be effective and acceptable, in order to realize the common goal. There is a significant tension between the present and the future. Actors are (to some extent) dissatisfied with the status quo. They envision improvements and formulate goals. They undertake individual and collective efforts of knowledge integration and implementation, and they seek to learn from experience.
- *Dialectic:* The key metaphors are "opposition" and "conflict". Dialectical change is less future-oriented because change emerges in the present through the opposition between parties (agents) that follow different claims and interests. Whereas a teleological process is based on high goal-consensus, a dialectical process is characterized initially by contradictory forces and, hence, a low goal consensus. "Change occurs when . . . opposing values, forces, or events go out of balance. The relative strength, power, or legitimacy of an antithesis may emerge or mobilize to a sufficient degree of force to overthrow the current thesis or state of affairs and produce a synthesis, which then becomes the new thesis as the dialectical process recycles and continues" [31] (p. 204).

Van de Ven and Poole [20] (p. 522) identify two further motors of change (life cycle, evolution) that are omitted here, because both refer mainly to "prescribed" change processes in which the social construction of tensions and effective ways of dealing with them are less prominent than in the teleology and dialectic motors of change. Change simply occurs due to deterministic or probabilistic "laws" that are embedded in natural or institutional conditions. However, it is important to note that Van de Ven and Poole [20] argue for the consideration of social change, in principle, as *complex* change in which all four motors may play a role [32].

This research note conceptualizes the social process of building resilience mainly as a *goal-driven* process of social change (teleology). We know that the formulation of goals to build resilience as a contribution to climate change *adaptation* is different to quantitative goal-setting in climate change mitigation. However, teleological processes are not always driven only by quantitative goals (targets). The vision of a desired end state in the future may encompass a multitude of frames (e.g., a "Leitbild" as a visual representation of the desired future urban form and infrastructure of a city [16]).

We furthermore acknowledge that it is increasingly important to consider the "political nature" of building resilience in cities and regions; however, social change, in terms of future-oriented collective action motivated and guided by goals, is at the heart of building resilience as well as sustainable development in general. Additionally, before studying complex change processes that encompass multiple motors of change, especially planned change *and* dialectic change [21], we should understand in more detail how actors deal with tensions, if they follow common goals. *Tensions also arise in goal-driven processes that are*

based on a high consensus between the actors involved. To show this in more depth, we need to consider the context conditions of social change.

2.3. Dealing with Tensions at the Interface of Science and Practice through Collaborative Projects

Goal-driven processes of social change to build resilience in cities and regions may encompass a multitude of tensions. Tensions may differ due to different contents and context conditions. For instance, in the context of climate change adaptation, there are different tensions involved in managing the risk of river floods due to well-known conditions, such as snowmelt in spring, in contrast to managing the risk of inundation due to torrential rain that affects only few localities (e.g., the tensions between measures upstream and their effects downstream in the case of the former, and tensions resulting from highly spatial selective torrential rainfall in case of the latter).

This research note elaborates on the contents of tensions of building resilience through referring to examples at a local level in Germany in the next section. Here, we focus on tensions that arise at the interface between conceptual resilience thinking and the translation of resilience concepts into the "real world" through implementation in practice. Of course, this note itself cannot go into the details of implementation (this would be an implementation study). Given that building resilience is a goal-driven process of social change that occurs at the interface of science and practice, we highlight three types of process patterns in dealing with tensions:

1. *Developing a strategic focus:* In principle, there is high complexity of goals and targets that are relevant for strategic spatial planning. If actors seek to consider as many goals and targets as possible, Wiechmann [18] (p. 143) labels this a synoptic approach to strategy development. In contrast, actors may also want to avoid overambitious and resource-demanding catalogues of goals and targets through focusing on only a handful of desired outcomes that are relevant in the specific situation of cities and regions. We argue that developing a strategic focus is especially important to accomplish knowledge integration at the interface of science and practice. Tensions arise not only with regard to the contents of knowledge integration, but also due to different *forms* of (or approaches to) integration.
2. *Setting priorities:* Setting priorities involves argumentation to justify explicitly why specific frames and actions of building resilience are more important than other frames and actions. There are also cases in which actors try to avoid explicit statements about the relative importance of frames and actions, because such statements may invite critics to question the priority setting. Healey [16] and others underline the value-laden "nature" of priority-setting in strategy development. In line with a strategic spatial planning perspective, we argue that it is by no means a trivial task to justify a priority of building resilience as *pro*-active ability in cities and regions.
3. *Negotiating compromise:* In the case of a trade-off, many "solutions are possible between two opposing poles" [33] (p. 309). Achtenhagen and Melin [33] (p. 309) highlight that finding a compromise in a specific situation "requires an understanding of the impact on both poles". The actors involved in urban resilience may determine through negotiation which solution between the two poles leads to a compromise that satisfies the claims and interests of the parties involved.

The purposeful cooperation of scientists and practitioners may happen in the form of a collaborative project. Projects are combinations of "people and other resources brought together in a temporary organization and process to achieve a specified goal. What distinguishes projects from all other organizational activities . . . is that a project is finite in duration, lasting from hours, days, or weeks to years and in some cases decades . . . a project organization is temporary and disposable by design. Each project brings together people and resources needed to accomplish a goal and disappears when the work is completed" [34] (p. 2).

The next section reports on examples of projects at the interface of science and practice to build resilience at a local level in Germany. The examples illustrate the three typical pro-

cess patterns of dealing with tensions in goal-driven processes of social change: developing strategic focus, setting priorities, and negotiating compromise.

Developing focus is the most basic form of dealing with tensions [17,18]. It is difficult, if not impossible, to set priorities and work out a compromise without a strategic focus. Hence, we proceed with this process pattern first.

3. Three Ways of Dealing with Tensions: Focus, Priority, and Compromise

3.1. Tensions in Knowledge Integration and Developing Strategic Focus

A goal-driven motor of change shows us why and how actors involved in building resilience initiate and implement change. Actors are motivated and guided by a common vision of a desired future end state to initiate change in the present and to use resources for measures to implement this envisioned end state. In the "real world", building resilience is, more often than not, *complex* change, in which many heterogeneous elements need to come together to generate the desired social change. The high complexity of elements is also implicit in the concept of urban resilience [3].

Consequently, to analyze and intentionally change urban systems, complex contents and forms of knowledge are relevant. At the interface of science and practice, efforts of knowledge integration are especially salient, for instance, to integrate the various contributions from different scientific disciplines and to integrate scientific knowledge with knowledge from practice (e.g., expert knowledge from public institutions, local knowledge of citizens and business organizations).

The knowledge integration for building resilience and DRR may be especially challenging. A disaster is defined as a "serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts . . . " [11] (p. 9). It seems plausible to expect that an actual disaster challenges the legitimacy, reputation, and effectiveness of those people (especially experts and further "knowledge workers") that have been involved, at central positions, in the various networks of urban systems in pre-disaster times. This should hold for an actual and, under specific circumstances, an anticipated disaster.

Hence, knowledge integration is not only a "technical exercise" that leads to "objective results", but also a highly political and contested endeavor. Tensions may emerge due to the contents and context conditions of building resilience. Tensions may also emerge because there are multiple approaches to knowledge integration. Following Tell [35], we distinguish between three approaches:

- *Sharing and transferring knowledge:* When two actors A and B share the same "body" of knowledge, this can be interpreted as redundancy in social action: A knows what B knows. Knowledge transfer is the process through which actors realize knowledge sharing. The main concern of transfer is matching message and medium [31]. After knowledge transfer, A knows what B already knew. Grant [36] points out that it is inefficient, if actors share *all* knowledge.
- *Using similar/related knowledge:* This approach is characterized by adopting a body of similar or related knowledge domains to accomplish a specific task. The term "integration" does not primarily refer to relations between the domains of knowledge involved, but to the common task and context of application. Efforts of integration are necessary and possible because the accomplishment of a specific task requires the application of already-related knowledge contents and forms.
- *Purposeful combination of specialized and complementary knowledge to accomplish specific tasks:* In this approach, actors combine highly different and hitherto unrelated knowledge by purpose and in regard to a specific task. For instance, A and B possess significantly different and unrelated, but potentially complementary knowledge. After knowledge integration, new knowledge emerges that is useful to accomplish a specific task that could not be accomplished with only the existing related or similar knowledge. Hence, knowledge integration in this third approach implies some degree

of innovation in the knowledge development. Tell [35] points out that knowledge combination is only possible if the involved actors also share some knowledge.

Knowledge integration is neither "one thing", nor is integration always a "good thing". There are different approaches such as knowledge sharing, using similar/related knowledge, and the purposeful combination of specialized knowledge; it is inefficient to share all knowledge. Efforts of combining specialized knowledge may fail because knowledge is not complementary. Knowledge integration often requires recurring cycles of co-operation and trust-building between the people involved. Trust is quickly "destroyed" but only emerges over time. This is also applicable in the goal-driven processes of social change.

It is important to consider both (1) tensions within and (2) tensions between the three approaches to knowledge integration:

- *Tensions within approaches to knowledge integration:* For instance, the third approach seeks to combine specialized and complementary knowledge. This requires that such knowledge is *available* for combination and that combinatory efforts are successful in the generation of new knowledge. The availability of specialized knowledge is based on in-depth experiences in a certain specialized knowledge domain, whereas efforts of combination need to draw "golden threads" through the complexity of specialized knowledge inputs. Van de Ven and Zahra [37] argue that both *too much* cognitive distance between actors, as well as *too little* cognitive distance, is negatively related to knowledge combination and innovation. Cognitive distance is one manifestation of tension between project partners. Knowledge integration at the interface of science and practice is facilitated if project partners follow a strategic focus that is positioned between too much and too little distance (see project example below).
- *Tensions between approaches to knowledge integration:* By definition, sharing and combining knowledge have tensions. Knowledge sharing means that actors have identical knowledge. Knowledge combination means that actors are able to combine knowledge that is different at the beginning and synthesized after combination. Hence, sharing thrives on homogeneity and the combination of heterogeneity. Tensions between sharing and combination are especially relevant at the interface of science and practice. In this context, it is plausible to assume that the actors involved in a collaborative project for building resilience have heterogeneous knowledge. Therefore, knowledge sharing may be the "bottleneck" for finding solutions to the pressing problems of building resilience. The project example below shows that this was actually the case in Dresden-Gorbitz.

As stated above, with regard to strategic spatial planning, developing a strategic focus is by no means primarily an exercise in strategic analysis, but a synergetic exercise that leads to collective action in urban areas, motivates people to participate in governance networks of urban systems, and facilitates knowledge integration at the interface of science and practice [16,17,38]. The project example "HeatResilientCity" (HRC), on dealing with summer heat stress and heat waves in the City of Dresden, illustrates this proposition.

The inter- and transdisciplinary project HRC is of medium size and involved both scientists and practitioners with a focus on the topic of heat stress in two cities: Dresden and Erfurt. The project lasted from 2017 to January 2021. Project partners applied a complex mix of methods to accomplish the project goal. Particularly noteworthy is the linking of measurement and simulation data across the scale levels of urban districts and buildings in order to map the effects of adaptation measures for resilience building, as well as the inclusion of the stakeholder perspective by means of surveys. A summary of the project goal, the constellation of partners, applied methods and results can be found in [39].

Summer heat is one of the most serious environmental impacts of climate change. Climate projections show a clear trend towards summer heat (e.g., an increase in both the mean and maximum temperatures, IPCC 2018). The projections for the Free State of Saxony also show an increase in temperatures. In addition to rising mean temperatures, especially in spring and summer, increased maximum temperatures are projected. The frequency

of summer days (Tmax $\geq$ 25 °C), hot days (Tmax $\geq$ 30 °C) and warm general weather conditions, such as in the summers of 2003 and 2018, will increase.

This applies in particular to dense urban neighborhoods without networked green corridors and ventilation strips. The performance and the so-called thermal comfort of people are significantly affected, both inside and outside buildings in their neighborhood. In order to maintain or even improve the quality of life of people in the context of climate change, it is necessary to focus on ensuring their coping capacity, and thus focus on resilience. The built environment—buildings and open spaces in the neighborhood as well as blue and grey infrastructures—can be intentionally adapted to absorb thermal effects to a certain extent, and thus reduce the exposure of people to heat stress and heat waves.

Against this background, some authors of this paper were involved in developing and implementing the project HRC [39]. In HRC, measures of climate change adaptation were implemented to intentionally change buildings and open spaces in two selected sample quarters in Dresden-Gorbitz and Erfurt-Oststadt each with a different urban structure and building types that are characteristic of many cities in Germany and Europe.

In the following, we focus on the project work completed in Dresden-Gorbitz. The most visible and largest part of the example quarter Dresden-Gorbitz is predominantly built up with industrial prefabricated concrete apartment buildings (so-called, post-war large-panel construction), which were constructed in the early 1980s. A large part of these buildings are owned by the housing cooperative "Eisenbahner-Wohnungsbaugenossenschaft Dresden eG" (EWG). Slightly more than twenty thousand people live on an area of about 200 hectares. Compared to the whole city, the district has a higher spatial concentration of socially and economically disadvantaged people. However, Dresden-Gorbitz has a relatively high proportion of green spaces.

HRC aimed to develop and implement innovative, socially equitable, and user-acceptable adaptation measures that supported the reduction in summer heat stress on people in buildings and open spaces. Selected measures were *physically implemented* in the sample neighborhoods. A quantitative and qualitative assessment of effectiveness served as the basis for the selection of suitable adaptation measures. The evaluation of measures was carried out using effectiveness analysis methods based on indicators that were suitable for measuring heat stress, in combination with user surveys on their perception [39].

In this paper, we do *not* report in detail the methods and results of the comparative analysis and evaluation of measures with regard to the buildings and open spaces in the sample quarter in the City of Dresden (see [39] for a summary). Our issue is the issue of dealing with tensions for building resilience, especially in terms of knowledge integration. *The development and implementation of HRC illustrates both dealing with tensions within and between approaches to knowledge integration.*

From 2013 to 2017, HRC developed as a *follow-up activity* of the large climate change adaptation project REGKLAM in the Dresden region, which lasted from 2008 to 2013. REGKLAM was characterized by a very broad and complex agenda of regional climate change adaptation topics. The agenda encompassed issues of adapting urban open space and built structures, economic relations, and policies related to health, biodiversity, agriculture, and forestry.

We hypothesize that the integration capabilities of the REGKLAM partners did not match this broad agenda [40]. Dealing with tensions was difficult, because too many topics were involved and the cognitive distance between many REGKLAM partners was too high. As a consequence, REGKLAM partners formulated a climate change adaptation program that lacked a strategic focus [40]. The climate change program is characterized as a complex catalogue of statements on goals, targets, and measures of planned climate change adaptation in the Dresden region. However, at present, the program seems to have had only an insignificant impact on the strategy development in the Dresden region [30].

Based on the REGKLAM project, the partners of HRC were able to establish a strategic focus on urban heat stress *at an early time point in project development*. Discussions on joint follow-up activities began immediately after the completion of REGKLAM and involved a

core of partners, now implementing HRC. The project partners of HRC agreed to focus on such issues of climate change adaptation that were related to strong and relatively robust climate change "signals" such as rising mean temperatures, a higher frequency of hot days and an increasing probability and duration of heat waves especially in urban areas.

The agenda of HRC was also focused in terms of addressing a complex set of measures for intended incremental change (not transformative change of the urban region). *We hypothesize that developing a strategic focus within HRC was a necessary precondition for knowledge combination at the interface of science and practice* (this was evident in the agreement of measures that were analyzed scientifically and actually implemented in the example quarter Dresden-Gorbitz).

HRC also illustrates tensions *between* the approaches to knowledge integration. Among the project partners from practice, HRC included the housing cooperative EWG as a formal partner, with its own budget provided by the federal government and allocated towards investment expenditures of the cooperative. Project implementation in Dresden-Gorbitz functioned "smoothly" not least due to the ownership structure of the EWG, which is a housing cooperative whose representatives can make their own direct decisions about their building stock.

Shortly after the start of the project, the selection of the buildings and a first presentation of the planned renovation measures by EWG took place at the end of 2017. Immediately afterwards, the EWG provided planning documents, such as plans of the existing buildings and renovation plans, so that researchers could work out specific concepts for measures. On-site inspections of the selected buildings and a comparable building that had already been renovated were carried out. As early as spring 2018, possible adaptation measures were coordinated between project researchers and the EWG. In summer, the tender documents were published and tenders were obtained from construction companies.

Adaptation measures were implemented in connection with EWG's existing renovation concepts on and in the buildings between 2019 and 2020 on a pilot basis. Communication processes between scientists and the housing cooperative could be managed without an intermediary property management company. The housing cooperative was interested in strengthening the future attractiveness of its rental flats, thereby, taking into account the affordability for the socially and economically disadvantaged people living there [39].

However, including a large organization with its own interests and resources may significantly limit the innovation potential of a project. For instance, in HRC, concepts for the optimization of summer thermal insulation were developed under the consideration of the *existing* renovation concepts of the EWG. Due to this fact, some potential adaptation measures were only partially considered or rejected under the time restrictions of the project duration.

Other measures required additional project-budget resources of the EWG due to the declared additional costs or caused higher rents, and thus potentially exacerbated social injustice. With regard to long-term planning, the economic evaluation of maintenance was of great importance in the selection of suitable adaptation measures. A preference was given to technically resilient measures that involved as little maintenance-intensive, failure-prone technical systems as possible.

In summary, a stable relationship between only a few partners from science and practice may help to specify the strategic focus on dealing with heat stress and heat waves in an urban area. However, this fit between strategic focus and social relations comes at a "cost". Innovative and transformative-oriented efforts to build resilience may require a more open and inclusive approach towards the selection, analysis, evaluation, and implementation of measures that refer to the mid- to long-term.

Hence, the example of implementing the project HRC in Dresden illustrates a tension in knowledge integration between short-term *knowledge sharing and knowledge combination* and facing the challenges of the mid- to long-term future. This also illustrates the proposition that developing a strategic focus is by no means sufficient for successful strategic spatial planning in general, particularly for building resilience at a local level.

Further process patterns in goal-driven social change are necessary for setting priorities and selecting actions.

3.2. Setting a Priority on Building Resilience and DRR as Pro-Active Ability

More implicit than explicit in the definition of urban resilience provided by Meerow and colleagues [3] (p. 45), are the tensions between resilience as a pro-active *and* reactive ability. Urban resilience is defined as the ability of an urban system to rapidly return to the desired functions in the face of disturbance. It remains open whether this is an *actual* disturbance of urban systems or a disturbance *anticipated* by actors that is pro-actively involved in the development of an urban area. It is possible that Meerow and colleagues [3] had the former in mind more than the latter. In contrast, the ability to transform urban systems to increase their future adaptive capacity explicitly points to anticipation and pro-action. However, pro- and reactive efforts of building resilience do not always fit together easily. This becomes clearer through considering in more detail different kinds and conditions of disturbance.

In a complex, uncertain, and turbulent world, some disturbance of urban systems is inevitable and increasingly "the new normal" (see [41] on "surprise management" and [42] on "Governance in turbulent times"). There are different kinds of disturbance. The nature of some disturbances is well-known in advance ("usual" or "known unknowns"). Still, when they happen and exactly how they happen may unsettle the lives of the affected actors. Other disturbances are less known ("unusual") or even completely outside the range of experiences and expectations of an actor ("black swans" or "unknown unknowns").

In a similar vein, in his seminal book on "Searching for safety", Wildavsky [43] (p. 93) distinguishes between "quantitative (expected) surprise" and "qualitative (unexpected) surprise". The nature of the former is known, but its specific manifestation when it occurs is unknown; the latter is impossible to expect in qualitative, and thus quantitative, terms. Otherwise, by definition, such a manifestation of surprise is classified as "expected surprise". Wildavsky [43] (p. 93) highlights the unexpected surprise as "true" surprise.

The terms "disturbance" and "surprise" highlight the different conditions for building resilience and DRR. The term "disturbance" is more action-oriented, whereas the term "surprise" points to cognition about the future. If there is a disturbance, something that could have been undisturbed is present. In the social sciences, disturbance is often related to institutionalized action. The term "surprise" focuses attention on the cognitive–cultural representations of future action and on the fact that expectations do not necessarily become "true" when the future unfolds in the present.

When an actor experiences surprise, there are, by definition [6], two relevant approaches to explaining the unexpected [13]: (1) an explanation through referring to the external context conditions of action (e.g., the change in socio-economic conditions, action of other actors) and (2) an explanation through the relatively appropriate expectations of an actor as internal context conditions.

Weick and Sutcliffe [13] argue that resilience requires that actors resist the temptation to attribute *success* mainly to *internal* conditions and *failure* to *external* circumstances. The actors interested in building resilience and especially DRR consider the full range of options: internal conditions as causes of success and failure (e.g., appropriate and inappropriate expectations) and external conditions of success and failure (e.g., good luck and bad luck).

Against this background, we argue that *building resilience as a pro and reactive ability has tension*. This tension may have many sources and manifestations which will be elaborated in the project example below. However, inspired by the work of Weick and Sutcliffe on "Managing the unexpected" [13], it is plausible to expect that tensions are related to governance networks of urban systems and that they are characterized by how actors involved in urban systems perceive and interpret the "world" around them. Weick and Sutcliffe explain:

> *"Notice that in the reactive world of the unexpected, the ability to make sense of an emerging pattern is just as important as is anticipation and planning. And the ability to*

> *cope with the unexpected requires a different mindset than to anticipate its occurrence. The mindset for anticipation is one that favors precise identification of possible difficulties so that specific remedies can be designed. A commitment to resilience is quite different. Resilience is a combination of keeping errors small, of improvising work-arounds that keep the system functioning, and of absorbing change while persisting"* [13] (p. 97).

Dealing with tensions is especially challenging when it comes to governance networks and people *with diverging mindsets*. Differences between mindsets cannot be easily resolved through the searching and finding of compromise because mindsets are (among others) complex, internally structured phenomena (e.g., a cognitive hierarchy of terms that shape the perception, interpretation, and action of human agents in urban systems; these are basic assumptions about crucial cause–effect relations). Some actors involved in urban systems may have a strong preference for anticipation and planned pro-action, despite experiences of the limitations of planning complex urban systems. Others may mainly follow a reactive and opportunity-driven strategy with an emphasis on short-term results and gains. There may also be actors that seek to strike a balance between pro- and reactive efforts of building resilience for DRR, but this then needs to be strengthened through political support and an appropriate resource base for action.

Hence, actors involved in building resilience and DRR need to consider the possibility of setting priorities that clarify the relations between different mindsets and beliefs in anticipation and planning. We propose that building resilience and DRR are related to a high priority of anticipation and planning, despite well-known voices that underline the limitations of effective planning in a complex, uncertain, and ambiguous world [13,43]. The following project example on managing extreme flood events in the Dresden region illustrates this proposition.

Disastrous flood events, such as the flood disaster related to the Elbe River and its tributaries in August 2002, as well as multi-level governance processes, led to changes in how flood risk was managed in European Member States. In summary terms, this change is described as a change from "conventional flood protection" to "flood risk management" [44] (p. 309).

This disaster-induced change in policies and practices also led to more attention towards managing the risk of extreme flood events [40]. Managing extreme events and their potential consequences is an important topic in many research fields and practices of designing resilience [2,45]. Not surprisingly, the notion of resilience was also discussed on managing the risk of extreme flood events (among other reasons for addressing issues of resilience in flood risk management [46]).

Scholars and practitioners alike emphasize that managing the risk of extreme flood events requires a pro-active approach towards risk reduction that highlights a comprehensive analysis, anticipation, evaluation, and planning [47]. Managing the risk of extreme floods as a contribution to DRR also seems to place a priority on prevention, mitigation, and preparedness.

As stated above, we argue that there are tensions between pro- and reactive efforts of building resilience that need to be considered. The following project example shows that this may justify a priority on anticipation and planning, *if the specific implications of considering extreme events are systematically worked out in strategic spatial planning.* In other words, an emphasis on pro-action requires justification based on a conceptual framework that is able to consider tensions between pro- and reactive efforts of building resilience. Adopting a tension-oriented perspective does *not generally* imply that a high priority for anticipation and planning is avoided (this would resemble the positions taken by [43] and [13] that are rather critical of planning).

We provide an example of analyzing and evaluating the advantages and disadvantages of two (planned) structural measures in a local case: the conventional measure of dike construction and the measure of house lifting in the village of Brockwitz in the City of Coswig/Saxony nearby the City of Dresden. The inter- and transdisciplinary project "House lifting in flood-prone areas based on the example of the Elbe village Brockwitz"

(2017–2019) was designed in the sense of a feasibility study using a mix of methods ranging from spatial hydrologic, hydraulic, and potential building damage modelling, analyzing the impacts on nature and landscape, the benefit–cost analysis, citizens and property owners involvement, as well as a general consequences assessment of action alternatives [47].

The Free State of Saxony has invested around EUR 2.6 billion in flood protection and in the elimination of flood damage to existing protection systems since the major flood event in 2002. The prioritization of new flood protection measures was based on the application of criteria that took into account the extent of the damage potential, the cost–benefit ratio, water management aspects, as well as particular impacts, consequential hazards and protection requirements. Based on these evaluations, many priority projects were established. However, the assessment also revealed that there were projects with a low priority and, consequently, cannot be implemented in the near future. The main reasons for this are often local or small-scale projects in combination with less favorable benefit–cost ratios.

Brockwitz, a village within the City of Coswig (with about 21,000 inhabitants) and located on the Elbe River, was also severely affected by flood events, especially those in 2002 and 2013. Due to local conditions, a stationary flood protection facility (dike) is contested here, as it represents a significant intervention in the cultural landscape and the historic townscape with a 1000-year history. At the same time, it is possible to protect only a relatively small number of buildings (affecting about 100 people), so that this project, from the perspective of the Free State of Saxony, had a low priority and the implementation of the measure in the near future is questionable.

This prompted the identification of suitable alternatives for risk reduction, an assessment of their feasibility, and an evaluation of the consequences for the village, its residents, and the surrounding area. Therefore, to maintain or even improve the attractiveness, as well as the quality of life, of the town and the natural functions of the Elbe floodplain, the City of Coswig was (and still is) pursuing the (potentially) innovative solution of house lifting for the flood-affected houses in order to mitigate flood risk in accordance with principles of sustainability while avoiding the subsequent costs. The following focuses on the comparison of house lifting and dike construction as alternatives for reducing the risk of extreme flood events, in terms of the potential damage to buildings in the relevant local area, in the village of Brockwitz. The complex issues of evaluating measures under a comprehensive and context-specific set of sustainability criteria (including issues of cultural heritage, and so forth) can be found in [47].

The aim was to investigate the key issues for building resilience and sustainable development with regard to the appropriate flood mitigation measures. Among others, the investigation encompassed the following components:

- Analysis of the building stock focused on three aspects: (1) A building typological differentiation of the settlement structure, as well as the incorporation of object-specific building parameters as a basis for damage modeling and the assignment of vulnerability information; (2) an assessment of the building stock, including the existing cultural monuments and the historic settlement with regard to their significance for the preservation of monuments, cultural history and the view of the place, as well as (3) an initial structural assessment with regard to technologically relevant boundary conditions for house lifting.
- A damage analysis was conducted through applying the model HOWAD/GRUWAD, which is characterized by (i) a multi-scale approach analyzing risks and risk mitigation, (ii) innovative methods to describe the urban structure and the vulnerability as well as (iii) a high spatial and contextual resolution of the resulting risks [48].
- Investigations were based on on-site inspections, individual case studies and archival research. Emphasis was also given to involve the affected citizens and property owners.

Inter- and transdisciplinary investigations were used as a basis for a comparative assessment between house lifting and conventional dike construction. Even though the assessment was still tentative and was carried out in the sense of a feasibility study, some

results can already be highlighted here: In the context of the conceptual framework outlined in the previous section, the most relevant result is that the protective effect of both measures, dike and house lifting, are somehow similar (approximately) up to a protection level of a flood event with an "Average Recurrence Interval (ARI)" of 100 years. For events with a higher ARI (a higher ARI corresponds to a lower probability of occurrence and, generally, a higher ARI corresponds with a lower flood probability and vice versa), the protective effect of house lifting exceeds that of the dike, while both measures achieve a similar cost–benefit ratio.

Figure 1 displays this result and illustrates how managing the risk of extreme flood events may contribute to building resilience and DRR.

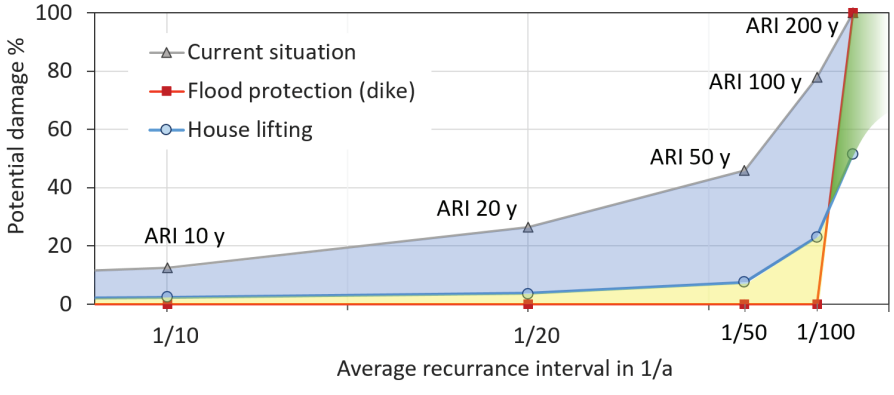

Figure 1. Risk curves for the case study area Brockwitz (Source: Author's own).

The risk curves in Figure 1 show the expected, potential damage to buildings depending on the ARI of the flood events. The expected damage values are displayed in percent related to the current situation. The colored, differential area between the curves of the current situation and the planned alternatives with mitigation measures indicates the prevented damage to buildings, respectively [49]:

- In case of a flood event with ARI between 10 and 50 y, both the construction of a dike and the measure of house lifting lead to a similar reduction in the expected potential damage.
- In case of ARI 100 y, the construction of a dike with this design standard will prevent all damage behind the dike. If the measure of house lifting refers to the same protected area, then, in this specific case, some damage to buildings is to be expected (about 20% potential damage).
- If a flood event exceeds the ARI 100 y, then the dike will provide no protection. In case of an uncontrolled, fast overtopping of the dike, this event could lead to a catastrophic situation, destroying parts of the dike structure and several buildings, via the flooding of their ground floors, and endangering life due to a potentially delayed evacuation. For this reason, areas protected by a dike are referred to as "risk areas outside floodplains" according to the German Water Management Act since 2018. In contrast, an extreme flood event with ARI 200 y will lead to only moderate flood levels for the lifted buildings and there is the possibility of preventing damage by mobile systems.

Figure 1 highlights these differences between dike construction and house lifting in terms of the expected damage potentials by the green color between the relevant curves and illustrates that house lifting improves building resilience with regard to extreme flood events.

It is worthwhile repeating that the measure of dike construction leads to the avoidance of potential damage up to a flood event with ARI 100 y, the design standard of the dike, whereas choosing the measure of house lifting could imply the pro-active acceptance of an increasingly higher damage potential relative to the dike construction up to its design level.

This is to say: In terms of the reduced damage potential, the advantage of house lifting becomes obvious only if decision makers consider extreme flood events for analyzing and evaluating measures ("outcome efficacy", [50] (p. 159)) beyond the typical German design standard of events with ARI 100 y.

The construction of a dike refers to two very different states of conditions that lead to flood damage potential in the case study area: (1) no damage potential up to the design level of the dike (flood event with ARI 100 y); (2) beyond the design level, the possibility of a local flood disaster. In contrast, the measure of house lifting aims to reduce damage for all recurrence intervals including water levels *above* the design water level of ARI 100 y. We hypothesize that the latter facilitates a stable and relatively high local flood (risk) awareness, whereas constructing a dike could tempt residents to develop a "false sense of security" behind the dike and to forget the possibility of extreme flood events in their local area.

In summary, the project example illustrates that setting a priority on building resilience as a pro-active ability through anticipatory analysis is well-justified, *because such a priority does not necessarily undermine* a strategic spatial planning perspective that pays due attention to the limits of effective anticipation and planning in an uncertain world. An anticipatory analysis enables actors interested in building resilience to calculate the specific implications of managing the risk of extreme (flood) events and to display them through means of visualization in the present. Of course, "good" anticipation and planning do not ensure successful efforts of building resilience [13]. This proposition may be applicable, especially with regard to managing extreme events in the context of climate change adaptation. Further processes of strategic spatial planning are needed "on the ground" in cities and regions.

3.3. Tensions in Analyzing Building Resilience and Negotiating Compromise

If actors agree on which future end state they want to realize through joint action, this does not mean that they also agree on every implementation detail to realize their desired common future. More often than not, there are differences in perceptions, interpretations, interests, knowledge and expertise between actors. Especially at the interface of science and practice in the form of a project, researchers with various disciplinary backgrounds and practitioners with different responsibilities, experiences, and expertise need to deal with tensions during the implementation of common goals.

At first sight, negotiating a compromise seems to be a widely applicable way of handling tensions during goal implementation. At second sight, we need to consider that compromise is effective if specific preconditions of dealing with a tension are provided. *Compromise is possible, if a problem has many feasible and acceptable solutions.* A spectrum of many solutions is based on the underlying dimensions of the problem that are characterized by scales that allow the continuous exchange of values ("trade-off"; the collective bargaining to reach a compromise between representatives of capital and labor being the typical example).

The following wants to show that dealing with tension through compromise is not only important when it comes to trade-offs between actors with different interests, but also with regard to the joint activities of scientists and practitioners to understand, describe, or analyze urban and building resilience.

Urban resilience is a highly differentiated and dynamically related complex phenomenon. Meerow and colleagues [3] (p. 45) provide a "simplified conceptual schematic of the urban 'system'" in which they distinguish four subsystems (as indicated above): governance networks, networked material and energy flows, urban infrastructure and form, as well as socio-economic dynamics. Meerow and colleagues [3] (p. 45) use the summarizing term "urban infrastructure and form" that emphasizes *relations* between

buildings, utilities, ecological greenspace, and transportation networks (see Figure 3 in [3] (p. 45)).

From the viewpoint of engineering, architecture, and urban analysis, it is important to accomplish a due disaggregation of urban infrastructure and form into the detailed analysis of single components, for instance, various types of residential buildings in cities based on selected dimensions of the building stock (e.g., building structure types and periods of construction [48]). The knowledge of the relations between the details of building types is then aggregated to the knowledge of the vulnerability (e.g., operationalized as damage potential, [48]) and resilience of spatial units within urban systems.

Hence, there is a tension, with regard to the object of interest, between generalization (urban resilience) and specification (building resilience), not as a fundamental conflict or dilemma, but as tensions in terms of manifold trade-offs in research and practice. Scholars and practitioners alike need to find ways to address this tension between specification and generalization in order to understand urban resilience [6]. The results of the analysis should be instructive to guide decisions, but still remain feasible while considering internal or external conditions which lie in the future. Here, the tension between general and specific resilience is no academic discussion but must respond to very practical questions of existing urban systems.

We claim that the positioning of the resilience perspective *in between* the poles of extreme specification and extreme generalization is in accordance with the different opportunities and limitations of the different working levels for yielding operational results and, as a consequence, is important for selecting a working level for producing the desired instructions for building resilience at a local level [51]. Researchers and practitioners may search for a compromise by combining levels of specification, with regard to the most important dimensions of building resilience.

In between strong arguments for the maximum specification or the search for general resilience, we perceive an "analytical space" (see Figure 2 below) to consider *trade-offs between specification and generalization*. Framing a tension as a trade-off facilitates the search for a compromise that satisfies the proponents of specification *and* general resilience. The following project example TRAFIS illustrates this through reporting on a "sustainability check" as a tool for local infrastructure development, in which the concept of resilience was included to address issues of infrastructure service supply security [51].

The inter- and transdisciplinary project TRAFIS (2017–2019) was dedicated to questions around the sustainability transformation of local and regional infrastructure systems. TRAFIS involved various, mainly qualitative, methods of transformation and transformative research. The development of the sustainability check was accomplished through a mix of methods, especially a literature analysis, the practical application of the sustainability and resilience check, and interviews with the managers of local infrastructure systems. For the application of the sustainability check with 115 German experts, the Delphi-method was applied [51].

Blue, green, and grey infrastructure are crucial systems within the larger urban systems. Where infrastructure services are disrupted, economic and social activities lose momentum and safety is endangered. As a result, the provision of infrastructure services has become a central topic of resilience research on infrastructure [52]. Generally, the resilience of infrastructure systems has long been a core feature of infrastructure operation. However, the attempts to explicitly differentiate the various facets of resilience, which might be of relevance for the operation and transformation of urban infrastructure systems, are relatively new.

Currently, this issue receives increasing attention due to two overlapping processes which are able to challenge, on a global scale, the high levels of security of supply of infrastructure in the Western world [51]:

- A highly dynamic transformation of infrastructure systems involving new technologies, structures, interconnections, and resources.

- The potentially increasing pressure on systems due to various perturbations (disturbances) from natural, climate-related hazards (inundations, heavy precipitation, heat, etc.), new dependencies within coupled systems and changing demand patterns.

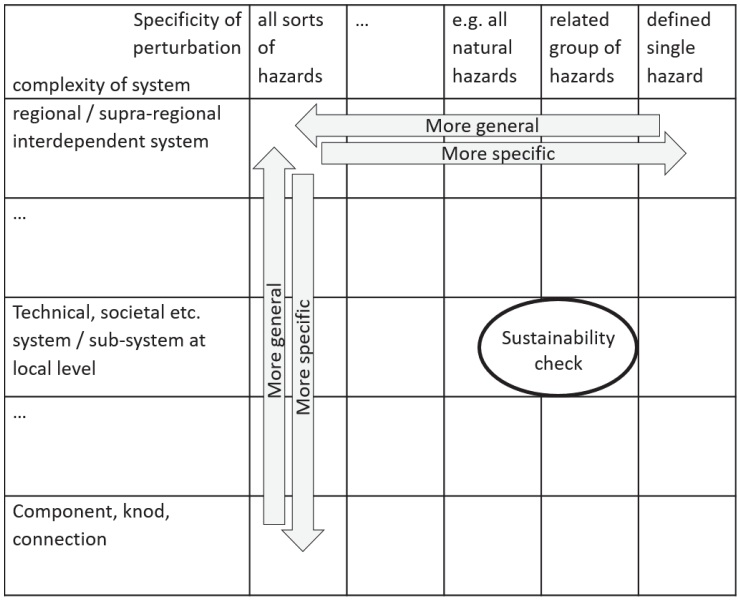

Figure 2. Locating the "sustainability check" through the specification of the focal infrastructure system and perturbation (own illustration based on [51]).

Innovative infrastructure solutions are, on the one hand, a challenge to the resilience of systems due to higher complexities, as well as new uncertainties and dependencies. On the other hand, they also are an opportunity for a more explicit and differentiated consideration of resilience in infrastructure development. Early phases in the development of new infrastructure solutions for urban systems are particularly promising for the consideration of resilience aspects, as the openness and scope for design may be relatively high with low sunk costs ("path dependency" in the context of urban development).

Therefore, the "sustainability check" aims to help "keep an eye" on the various infrastructure-specific aspects of sustainability before formal decisions create path dependencies. Given this challenge and based on multiple research projects, a team of scholars developed (on behalf of the German Environment Agency) the "sustainability check" for an in-process sustainability assessment of local infrastructure innovation projects [51].

The check helps to understand the sustainability effects of a new infrastructure solution. Thus, the check is a *screening instrument* that also provides indications of potential challenges, which require special attention in the development of the solution in order to minimize undesired effects.

Currently, the "sustainability check" includes over 30 criteria to operationalize the assessment of the sustainability of innovative infrastructure solutions at an early stage of development. Three dimensions form the basic framework for making the sustainability concept operational by providing criteria that can be applied at an operational "real world" project level [51]:

- Security of supply (performance and resilience) (14 criteria);
- Natural resources (14 criteria);
- Economic viability and social justice (six criteria).

In this context, an operational stability-oriented understanding of resilience ("bounce back") based on "engineering resilience" is mainly adopted [51]. To assess resilience, system properties describing the structure, resources, and abilities of the regarded system are differentiated by using ordinal scales. Bearing local level community resilience in mind, the work mainly addresses the operation and administration of local level infrastructure utilities engaged in short- and middle-term innovation processes as a part of a local sustainability transition.

However, even in case of a focus on local infrastructure development, questions arise on how to deal with the tension of specification and generalization, not in the sense of a dilemma or indivisible conflict, but as a trade-off. In order to achieve this, the "sustainability check" is located in relation to two dimensions of specification and generalization (Figure 2).

Each infrastructure is in itself a complex system. By providing essential services, infrastructure systems are deeply interwoven into society. Most infrastructure is enabled by a densely related interplay of technological, socio-economic, and ecological elements and conditions. The functioning of such socio-technical [53] or better socio-eco-technical systems [54] integrates physical artefacts, technologies, societal expectations and behavior, market patterns, institutional structures, knowledge and skills, legal regulations, technical standards and natural resources. To consider this complexity and to be specific about its relevance for the "sustainability check", five levels of specification describe the analytical space:

- Single components,
- Artefacts (meaning a functional agglomeration of components);
- Sub-systems that include various artefacts connected by communication and control to form the first complex functional units (the "sustainability check" focuses on this level of specification);
- Interconnected and interdependent (sub-)systems from different domains, focusing on socio-technical or socio-eco-technical systems;
- A regional-supra-regional level of interwoven cross-domain systems.

Furthermore, Figure 2 describes a continuum of perturbations from a focus on a single hazard to the extreme of considering all uncertainties related to natural and man-made hazards as envisioned by the concept of general resilience [55]. As the "sustainability check" is an instrument of screening, it is often plausible to consider multiple, but related, types of perturbations (e.g., climate-change-related hazards such as weather extremes). Specific infrastructures may face disturbances from only one hazard or very few.

Based on the analytical space depicted in Figure 2, scientists and practitioners are able to agree on multiple compromises to specify the level of infrastructure complexity and the spectrum of disturbances (or perturbations) that they wish to consider in a joint project:

- They may jointly work on only one component of a focal infrastructure system, while paying apt attention to all possible hazards;
- They may jointly focus on a very complex regional infrastructure system that is embedded in international relations. Only a few and very specific perturbations that challenge the security of the system are taken into consideration;
- Seemingly, the "sustainability check" has a different aim to these two possibilities. The check integrates information on complex local infrastructure solutions that are (potentially) innovative and at an early stage of development. Further, the check considers multiple, but not all possible, perturbations to a secure infrastructure service provision.

In summary, the check illustrates how a compromise can be found based on the levels of specification (generalization) with regard to the relevant dimensions of building resilience. This project example also illustrates the proposition that negotiating compromise is, in case of concluding negotiations that lead to compromise, contingent on complex success factors. In the face of the high complexity of urban systems, scientists and practitioners need to agree on an "analytical space", such as proposed in Figure 2, to jointly determine

a spectrum of the possible options for collaborative work. In turn, the positioning of the resilience focus in the analytical space can be adapted to the specific needs in collaborative projects at the interface of science and practice in the sense of data, methods, and the financial resources available for the analysis. This again underlines the proposition that negotiating a compromise is based on developing the strategic focus of scientists and practitioners and the ability to set priorities in the face of tough decision demands.

4. Conclusions

It is the aim of this research note to argue that the umbrella term "tension" is useful if different kinds of tensions and the ways of dealing with them are considered. Based on a strategic spatial planning perspective and an understanding of social change as a goal-driven process ("planned change"), we highlighted three kinds of tensions and ways of dealing with them:

- *Dealing with complexity in knowledge integration through developing a strategic focus:* Especially at the interface of science and practice, knowledge integration is characterized by the complexity of contents, frames, and approaches to integration. We differentiated tensions within and between approaches to knowledge integration (knowledge sharing, application, and combination). Developing a strategic focus is crucial in the face of increasingly high expectations of how knowledge on building resilience in the context of climate change is generated and transferred into practice. In conclusion, we argue that strategic focus must be understood as a *necessary* condition for a successful knowledge integration to build resilience to natural hazards at the interface of science and practice.
- *Dealing with diverging mindsets towards planned change through setting priorities:* Even if the scientists and actors involved in urban systems follow a common goal for building resilience, they will often approach goal accomplishment with different mindsets. This is due to various reasons (e.g., variations in institutional constraints of action, different "logics" of scientific disciplines and practice fields). Therefore, goal-driven processes of building resilience are characterized by the demands of setting priorities, and this is exactly what a strategic spatial planning perspective attempts to achieve. Thereby, setting priorities entails both (1) the statement that A is more important than B and (2) the justification of why this is the case, with regard to a specific situation and frame of justification. We conclude that this understanding of setting priorities is important for dealing with building resilience and DRR in the face of voices that highlight the limitations of planned change in an uncertain world and especially the limits of planning for extreme events [56].
- *Dealing with trade-offs in analyzing the contents of building resilience through negotiating compromise:* Trade-offs are often conceptualized as trade-offs between the interests of agents involved in urban systems. By contrast, in this research note, we argue that trade-offs also arise at the interface of science and practice with regard to the complexity of urban systems and the spectrum of possible natural hazards. Based on the strategic focus for building resilience and the agreement on how to set priorities, scientists and practitioners may be able to work out a complex "analytical space" (see Figure 2 above) in which a multitude of specific compromises serves as a frame of negotiations for scientists and practitioners, regarding how to develop innovative solutions to the pressing problems of climate change adaptation in cities and regions.

The three kinds of tensions and the ways of dealing with them through focus, priorities, and compromise indicate that the efforts of resilience building are as much about dealing with the complexities of frames as they are about motivations, interests, power, and institutional constraints of action. This also indicates that our research note is written from a micro-perspective on building resilience to natural hazards. Such a perspective needs to be combined with meso- and macro-oriented approaches that highlight the complexities of institutionalized action and institutional change. This brings us back to the typology of motors of social change: Building resilience is a complex change that encompasses multiple

motors. Future research and practice need to consider both the interplay between planned change and the politics of pluralistic, as well as the highly confrontational ways of adapting to climate change [57].

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Article

The Language of Risk and Vulnerability in Covering the COVID-19 Pandemic in Swedish Mass Media in 2020: Implications for the Sustainable Management of Elderly Care

Katarina Giritli Nygren [1,*], Maja Klinga [2], Anna Olofsson [2] and Susanna Öhman [2]

[1] Forum for Gender Studies, Department of Humanities and Social Sciences, Mid Sweden University, 85170 Sundsvall, Sweden
[2] Risk and Crisis Research Centre, Department of Humanities and Social Sciences, Mid Sweden University, 83125 Östersund, Sweden; maja.klinga@miun.se (M.K.); anna.olofsson@miun.se (A.O.); susanna.ohman@miun.se (S.Ö.)
* Correspondence: katarina.giritli-nygren@miun.se

Abstract: The consequences of the COVID-19 pandemic—in terms of climate, economy and social aspects—cannot yet be fully assessed, but we can already see how the pandemic is intensifying already existing socio-economic inequalities. This applies to different population groups, particularly the elderly. In this article, our goal is to identify the linguistic constructions of elderly citizens in Swedish mass media coverage of the COVID-19 pandemic in 2020 from a sociological and corpus linguistics perspective. More specifically, our aim is to explore the discursive formations of the elderly in Swedish media during the pandemic and how these formations relate to risk as well as the discursive constructions of in- and out-groups. Drawing on corpus-assisted discourse studies (CADS), inspired by discourse–historical analysis (DHA), we examine the media coverage of COVID-19 by three Swedish newspapers published during 2020: *Aftonbladet*, a national tabloid; *Svenska Dagbladet*, a national morning newspaper; and *Dalademokraten*, a regional morning newspaper. In this article, the news articles and their messages are considered performative to the extent that—for example, at the same time as a story is expressed—the elderly are at risk of becoming seriously ill due to COVID-19; moreover, a position of vulnerability for the elderly is simultaneously created. The result reveals that the elderly were constructed as an at-risk group, while visitors, personnel and nursing homes were constructed as being risky or a threat to the elderly.

Keywords: elderly; pandemic; corpus-assisted discourse studies; media coverage

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1. Introduction

The COVID-19 pandemic is a multi-hazardous risk with disastrous consequences, including its compounding effects on climate-related, economic and social domains. Over the past year, we have witnessed how the pandemic has escalated socioeconomic inequalities around the world with unprecedented consequences [1]. One of the social groups that has been very much present in the communication and debate regarding pandemic risks and risk-groups are the elderly; it has been argued that there is an ageist discourse underlying how we have come to understand the pandemic, e.g., [2]. In a previous study on the development of crisis narratives and struggles over legitimacy during the first phase of the COVID-19 pandemic in Swedish news, we identified conflicting narratives in the public debate related to the elderly [3]. One such debate can be best described as utilitarianism and striving for herd immunity, and the other as viewing human beings—including the elderly—as ends in and of themselves, a kind of 'herd humanism'. The elderly, defined as an at-risk group in the pandemic, were both associated with narratives regarding herd immunity being sacrificed for the greater good and with discourses encapsulating humanism that argued for a re-inscription of values associated with ageing.

In a commentary that includes over 20 researchers from the field of ageing studies, the following question on ageism and COVID-19 was posed and answered: What does our society's response say about us? According to these researchers the pandemic has accentuated the public discourse that questions the value of elderly:

The COVID-19 pandemic has accentuated the exclusion of and prejudice against older adults. The current crisis highlights a disturbing public discourse about ageing that questions the value of older adults' lives and disregards their valuable contributions to society [4] (p. 693).

Although this study did not include Sweden, there are other studies on the COVID-19 pandemic that confirm a similar situation in Sweden [5,6]. A few months after COVID-19 had begun spreading in Sweden, it became evident that Sweden—in comparison with its Nordic neighbours—had failed to protect the elderly [7]. Research has revealed that a lack of competence, hygiene routines, clear guidelines, low staff continuity, neglected resources and insufficient protective equipment exacerbated the spread of infection in institutional care homes for the elderly. These shortcomings did not solely arise during the pandemic; rather, they illuminated that elderly care has largely been de-prioritized for a long time [8]. However, inequality has not been generated by the pandemic itself; it is the already-existing unequal opportunities and positions in society that have enhanced the consequences of the pandemic [9].

Prior to the pandemic, existing research indicated that older citizens were often associated with discourses of elderly care, risk and vulnerability—not as a marker of old age, but instead as a challenge for society [10]. Putting these results into perspective, Zinn and Macdonald [11] revealed that risk reporting in print news media has changed over time and moved towards a greater emphasis on social groups in daily life (e.g., women, elderly and children) in stories. Nevertheless, simultaneously, these groups were related to less agency in linguistic expressions [11]. Thus, to better understand vulnerability management and resilience under disasters, we must investigate how everyday social groups such as the elderly are narrated about and constructed in terms of risk in public debate. To do this, we utilize Ruth Wodak's discourse, historical analysis (DHA) [12], as it is particularly well suited for uncovering discourses on inequality and discrimination [12] in quantitative corpus linguistic analyses as well [13]. Discursive analyses of risk and normalization processes are a means of uncovering how the 'language of risk,' or risk discourses delimits how something is defined or even what is possible to think and say at a certain time—for example, during the pandemic [14] (p. 1633). Risk discourses can be explored as discursive imperatives, underwritten by their accompanying values and underlying morals—for example, who is framed as being at-risk (or is 'a risk' for that matter)—is entangled with positions of subordination and decisions regarding which lives are morally worth saving and those which are disposable [15]. By beginning from discourses regarding the elderly and COVID-19 in media reports, we can capture the processes that define and represent the elderly in relation to the pandemic as well as what is considered 'natural' and taken for granted in these reports [16].

1.1. Problem and Aim

In Sweden, as in other countries, the elderly are one of the population groups that have suffered the most from the pandemic, not only because of a vulnerability to the virus itself but also due to the position of the elderly in Swedish society [5]. The concept of ageism appears to have arisen during the COVID-19 pandemic in Sweden [5] as well as in many other countries such as the US, UK and Germany [17–21]. Overall, the findings reveal that the elderly are viewed as victims, as fragile and an at-risk group, which are images that connect to wider social practices and discourses regarding the elderly and ageing. Ageist discourses can contribute to the exclusion and subordination of the elderly; in order contribute with knowledge regarding how ageist discourses might operate in times of crisis, this study follows up on our previous qualitative analysis of the ideological conflicts present in the framing of the pandemic with a quantitative corpus linguistics analysis of

articles published in three Swedish newspapers during 2020, with a particular focus on the elderly. Our aim is to explore the discursive formations of the elderly in Swedish media during the pandemic and how these formations relate to risk as well as the discursive constructions of in- and out-groups. With the point of departure in discourse–historical analysis [12] (p. 72)—the following five research questions guide our analysis:

1. How are elderly persons named and referred to linguistically in Swedish media?
2. Which nouns, adjectives, verbs and adverbs are attributed to the elderly?
3. By means of which arguments are discrimination and suppression expressed?
4. From which perspectives or viewpoints are these arguments expressed?
5. Are the respective utterances intensified or are they mitigated?

1.2. Empirical Context: Elderly Care in the Swedish Welfare System

In order to give the study context, a short background on the Swedish welfare system and how it affects the elderly care and nursing homes follows. The pandemic has actualized questions about welfare, elderly care and nursing homes by exposing many weaknesses in the Swedish welfare system. The Swedish welfare system is supposed to care for the citizens from kindergartens, schools, health care to nursing homes or elderly care, and has in many ways replaced the function of the family to secure care and welfare. The working environment in Swedish nursing homes and in the elderly care has worsened since 1990 when Sweden adapted and began to practice New Public Management (NPM) within the Swedish welfare system [22]. NPM has also invited healthcare companies with profit interests as actors in the Swedish elderly care, and research shows that profit interests has led to a lower number of employees, lower educational level and a lower percentage of permanent employees in the care facilities [23].

The elderly care has been de-prioritized for a long time in Sweden [5,8], but the pandemic has brought them into focus: unsafe employments, lack of good and functioning hygiene routines, safety equipment and lack of competence all were reasons for the high spread of COVID-19 in nursing homes. Therefore, in 2020, the Swedish government founded a new commission called the "Corona Commission" and gave them the task to investigate the situation in Sweden during the pandemic with a focus on the elderly; the commission concludes in the report The elderly care in the pandemic (2020) that the Swedish strategy of protecting the elderly has failed. The report highlights the need for greater expertise, reasonable working conditions and more staff as crucial for the Swedish elderly care [24]. It is in the face of this situation that the results of the study should be interpreted.

2. Previous Research and Theoretical Framework

There are numerous studies on media reporting on the pandemic and discourses around the pandemic [25]. The reporting on COVID-19 in media uses metaphors to support the public to grasp the pandemic and its consequences. Elements of ideology and political initiatives are also part of the framing of the pandemic by the mass media. For example, war frames are common in the reporting in China [26], the United Kingdom (UK) [27] and Sweden [28]. This is confirmed and further analysed by a US study that found that newspaper coverage on COVID-19 is highly politicized, network news coverage somewhat less so, and both newspaper and network news coverage are highly polarized. The findings suggest that the high degree of politicization and polarization in media coverage may have contributed to polarization in the attitudes of people toward the pandemic in the US [18]. As in our own previous study on the public debate in Sweden [15], struggles over ideological dominance were found both in US and Chinese newspapers [29], with clear nationalist anchoring in ideology bias practiced through the selection of topics and the tone of reporting [29].

The COVID-19 pandemic has highlighted how ageist language is employed and ageist stereotypes are used to characterize older adults [19,21]. Ageist language is used even though the disproportionately negative outcomes for older adults in the pandemic partially

reflect the social and economic inequalities that are manifest throughout the life course of marginalized groups. They also reflect major problems with institutional living [20]. An American study showed that media sources consistently described older adults as being vulnerable during the COVID-19 pandemic [19]. The study showed that national news sources engaged in both explicit and implicit ageism, for example by associating different words describing weakness and exposure with the elderly [19]; see also [17]. Another study reveals that classifying older adults, based on age, as a higher risk group of COVID-19 is potentially reinforcing ageism [21], which is an aspect that can accelerate the risk of social isolation and heighten the levels of psychosocial distress. Skoog [5] argues that formulations of the elderly as the primary 'at-risk group' subsequently resulted in restrictions specifically directed towards this demographic, which has created a form of ageism that stigmatizes the elderly. Thus, all people over a particular age were treated like a homogeneous group and faced with more extensive restrictions than other groups. This is also confirmed in studies of newspaper photos related to the COVID-19 pandemic [17]. A Finnish study identified different social positions for age groups: children as controlled pupils and also as happy and playful; youth as future-oriented graduates and reckless partygoers; adults as experts, professionals, caretakers and active recreationists; the elderly as isolated loners. The results correspond to the positions of villains, heroes and victims, respectively [17]. The restrictions also reinforced the stigmatized feeling of previously independent older individuals, when many of the elderly suddenly became dependent on others. Thus, the management of the pandemic caused a mental construction of the elderly as being fragile and almost the only ones who could become ill with the virus [5]. Further, the Swedish public debate in the spring of 2020 mirrored this focus on restrictions for the elderly and other risk mitigation actions that the government and the Swedish Public Health Agency had implemented at the time [15].

The Performativity of Risk, Discourse and Its Normative Implications

Following Fairclough [30], we consider discourse as a representation of a certain domain of social practice from a particular perspective, and the relationship between discursive practices and the settings in which they are embedded are considered as dialectic. Thus, as Wodak [12] (p. 63) indicates, "discourses as linguistic social practices can be seen as constituting non-discursive and discursive social practices and, at the same time, as being constituted by them." Discursive analyses of risk in the public debate can uncover how certain social groups and institutions are defined in terms of risk, based on underlying values and morals. According to Hunt [31], the boundary between normative judgements of risk and objective hazards has become blurred, and a hybrid between moral discourses and discourses of risk has been created. The moral components of risk discourses imply that individuals are expected to self-regulate based on the norms of what it means to live a righteous life [31,32]. The restrictions during the pandemic are obvious examples of this, but also media reporting and everyday talk regarding the risks associated with COVID-19 behave in a performative manner. As a subject, one acts in accordance with performative risk discourses, as the work of normalization processes, where the conduct of the individual is governed through moral discourses of responsibility, a process which then masks itself by framing the conduct as the outcome of free and individual choice [33].

Within the discourse of responsible risk avoidance, behavioural differences are often considered a matter of choice [34]: if you do not adhere to recommendations, it is considered a choice you have made. The concept of the 'right choice' or the imperative to act in a certain manner in accordance with public recommendations also has the effect of dividing people according to those who are considered to be more or less at risk. It is inescapable that talk of being 'at risk' carries allusions to death—the embodiment of biological materiality, the mental and spiritual extremity, the ultimate risk. Simultaneously, ageing and the inevitable hazards of growing older form another arena in which the autonomous self is expected to behave and act wisely. Thus, growing old has itself become a social, reflexive and managerial risk in which the political domain is bound up with ideological and

philosophical questions of self-governance [35,36]. A critical discourse analysis of how older people are portrayed during the pandemic can also reveal how ageist discourses interact with 'responsibilisation' and risk discourses and, thus, reinforce existing unequal social practices and structures [37].

Such a theoretical analysis, with its point of departure in critical discourse analysis, can be used to disentangle the manner in which the performativity of risk is intertwined with the processes by which age is constructed in a system, and through which risk discourses can be mobilized and used to uphold other formations such as social norms. This normalizing act often occurs along contemporary hierarchies of power—the act of naming is performative precisely because it initiates the individual into the subjected status of a subject [38] (p. 121). This implies that media news, when naming risky or at-risk subjects, brings them into being subjects for risk discourses and their underpinning values and priorities. Similarly, macro-topics such as COVID-19 interrelates such discourses [12]. For example, from our own previous study, the elderly were described in an editorial piece as having dementia and being close to death anyway [3]. Thus, we turn to a critical discourse in our study—historical analysis—to enable critical investigation and challenge what has been taken for granted thus far [37] (p. 2).

3. Materials and Methods

The methodological framework used in this study draws on corpus-assisted discourse studies (CADS) [39,40], which is a combination of corpus linguistics and discourse analysis. The corpus linguistics quantitative analysis is used to identify, quantify and compare the most prominent terms that occur in the coverage of the elderly during the pandemic, combined with a qualitative exploration of broader linguistic patterns related to these representations. In our previous study [3], we identified ageism discourses in a selection of new articles; here, we apply DHA in the analysis of all published articles in three newspapers during an entire year to avoid the hidden danger in qualitative analysis of unintentionally singling out manifestations of the analyst's interest [13].

The corpus consists of 26,841 articles from the year 2020 containing the word 'COVID-19' or 'Corona' from three Swedish newspapers: an agenda-setting unbound conservative morning paper called *Svenska Dagbladet*, with approximately 750,000 daily readers; an independent social democrat tabloid newspaper called *Aftonbladet*, with almost 3,000,000 daily readers; and a local independent social democrat newspaper called *Dalademokraten*, with 30,000 daily readers. This mix of newspapers aims to represent both national and local perspectives as well as different political directions. The number of articles was low at the beginning of the year; subsequently, it was followed by a peak in April 2020, with over 4500 articles on Corona or COVID-19. The reporting then stabilized with a second smaller peak in November 2020 (see Figure 1). The pattern is the same for all three newspapers; the statistical analysis confirms that the kind of analyses that are relevant here do not reveal any differences among the three newspapers. The first two months of reporting focused on the economic consequences of the outbreak of a new Corona virus in Wuhan, China. From March-end onward, the mass media reporting became more diverse and began focusing on domestic consequences along with comparisons of how other countries were handling the virus as opposed to the Swedish strategy.

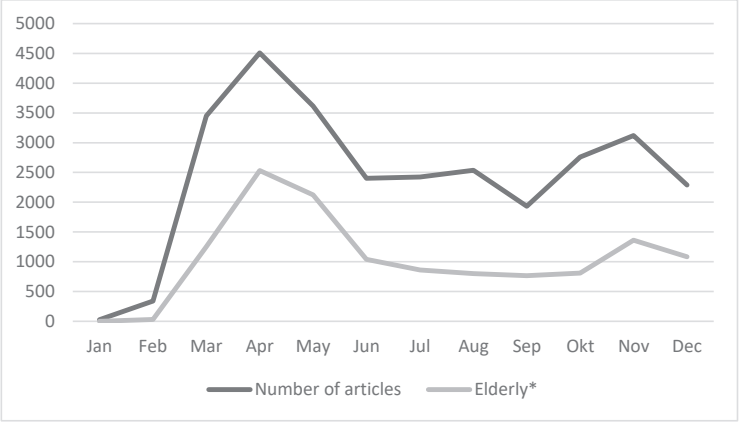

Figure 1. The number of articles published during 2020 in three newspapers in Sweden, which contained the search terms 'corona' or 'COVID-19' and the number of times the word 'elderly' * appears in the articles.

In total, the number of word tokens in the corpus is 16,487,463 and the number of word types is 272,568. The former represents the total count of words in their raw forms, while the latter illustrates the number of unique words. Using corpus linguistics and the program AntConc, we searched for how the elderly are framed in the news by analysing which words are more likely to occur in close relation to the mentioning of 'elderly'. This is an effective method when it comes to merging the qualitative and quantitative aspects of a text mass where the linguistics are of interest. The method places specific terms within a context by systematically listing each context in which a defined word occurs [39] (pp. 71–72). The search revealed five words to the left and right of the search term 'elderly' ('Äldre*' in Swedish). The most frequently occurring words were listed and subsequently analysed (see Table 1). The word classes we used are nouns, adjectives, verbs and adverbs; we consequently excluded non-discursive classes, such as pronouns and prepositions. This choice was made in order to follow Baker's [40] example, who suggested the exclusion of grammatical function words in this part of the process.

Table 1. Collocations of 'elderly' within the pandemic corpus (search term Äldre; frequency).

Rank	Frequency	Frequency (Left)	Frequency (Right)	Statistic	Collocate Original	Collocate
14	841	310	531	6492.13755	personer	Persons *
24	375	348	27	4049.87572	skydda	Protect
25	680	432	248	3690.05678	COVID	COVID *
27	312	126	186	3391.09849	boende	Accommodated
32	305	213	92	2650.96026	personal	Personnel *
33	208	185	23	2625.55257	besöksförbud	Visitors' curfew
34	368	337	31	2604.88127	våra	Our
43	226	152	74	2223.83903	särskilda	Special
45	202	112	90	2164.43774	boenden	Accommodation
48	246	223	23	2154.17367	landets	The country's
49	252	182	70	2094.99437	smittan	The infection
51	179	51	128	1964.81754	riskgrupper	Risk groups

Table 1. *Cont.*

Rank	Frequency	Frequency (Left)	Frequency (Right)	Statistic	Collocate Original	Collocate
53	154	30	124	1865.06245	hemtjänst	Home care
54	225	109	116	1849.24958	vård	Care
57	140	122	18	1769.57866	besöksförbudet	Visitors curfew
66	168	130	38	1505.83157	besök	Visit
67	233	61	172	1485.53997	människor	People *
69	275	107	168	1450.22064	Sverige	Sweden
70	107	71	36	1361.34043	sköra	Fragile
73	139	60	79	1330.41401	anhöriga	Relatives
77	170	73	97	1274.86500	sjuka	Ill

* words that do not add meaning to the analysis.

Further, the quantitative aspect of this study is based on corpus linguistics. Corpus linguistics is a beneficial method when certain aspects of a large amount of text are of interest [40]. It is also a suitable method for CADS and DHA [13]. A number of routine processes and procedures are involved when searching a corpus in order to recover, organize and display linguistic information. The three steps that were used in this article were word frequencies, collocations and concordances [40], which also function as the framework for the analysis. The first step, analysis of frequencies, was used to identify how often the word-form that is under study—the so-called 'node'—occurs; in our case, the node is 'elderly'.

The next step of the analysis was to identify collocates, which Stubbs [41] (p. 21) defined as 'frequent co-occurrence'. Thus, in this stage, we investigate the node of interest's most frequent co-occurrence with other words. In our analysis, five words to the left and right of the node were analysed in the search of the most frequent co-occurrences. A collocates analysis using log-likelihood as the statistical measure has made it possible to analyse how the elderly are described by showing which other words appear in close proximity to the searched term. The higher the value of the likelihood, the stronger the correlation with the investigated node—that is, 'elderly'. Collocations are used in order to discover repeated or typical lexical choices that are used in media reporting on COVID-19 and the elderly. Such recurrent words are understood as reflecting practices by which communities express, interpret and evaluate the elderly, thereby indicating how they are framed in discourse. As Stubbs [41] (p. 188) suggested, we do not view collocations simply as lexical items, we also see them as having the possibility to act as 'nodes around which ideological battles are fought'.

The third step is the concordance analysis. Overall, the analysis of the frequent lexical words reveal a few of the most important concepts in the corpora, but a more detailed analysis of these lexical items in the present context is crucial. Context plays a significant role in signalling the relationships among particular words, which is impossible to achieve by merely considering word frequencies and co-occurrence alone. To understand the context of the words occurring in close relation to the elderly, a concordance analysis has been used in order to analyse the context in which the words occur [42]. Concordances are lists with lines that display all the occurrences of a search term. Following others who have used CADS, we believe that the concordance lines express social processes and phenomena. In order to investigate how they reflect social practices, we have used DHA as developed by Wodak [12], which has also been used by others in combination with corpus linguistic analysis [43].

Discourse Analytical Strategy

The specific discourse-analytical approach, discourse–historical analysis (DHA), applied in this study was first developed in order to trace the constitution of negative and discriminating images in public discourse, particularly discursive strategies to present 'us' positively and 'them' negatively [13]. Therefore, DHA is particularly well suited for analysing racist and discriminating discourses [35]. In our case, we are interested in how

the elderly were framed in Swedish media during the COVID-19 pandemic and the normative effects it might have. Following DHA, the first step is to identify if stereotyped discourses are present in the investigated corpus [12]; as mentioned in the introduction, we already found tendencies of ageism discourses in the Swedish public debate on COVID-19 in a previous study [3]. The second step is to identify discursive strategies, and the last step is to examine the linguistic means and the context-dependent linguistic realizations of discrimination or, as in this case, ageism [12]. In this analysis, we place the main focus on the second step (see also [43]) to analyse the discursive strategies, as we have already identified the presence of ageism discourses in our previous study [3]. Wodak [12] (p. 73) defines a discursive strategy as "a more or less accurate and more or less intentional plan of practices (including discursive practices) adopted to achieve a particular social, political, psychological or linguistic aim". Five strategies, first practiced by Wodak [12] (p. 73), are often used in DHA, each with an objective and particular devise to perform the specific discursive strategy [37] (p. 29), [42]:

(1) Referential or nomination strategy, which aims at focusing on the discursive construction of in-groups and out-groups and is realised through discursive devices such as membership categorizations, metaphors, and metonymies and synecdoches.
(2) Predication strategy, which aims at labelling social actors more or less positively or negatively and is realised through stereotypical attributions of traits and implicit and explicit predicates.
(3) Argumentation strategy, which aims at justifying positive or negative attributions and is realised through the use of topoi for justifying political inclusions or exclusions.
(4) Perspectivation strategy, which aims at positioning the speaker's point of view and is realised through discursive devices, such as report, description, narration, or quotation of events and utterances.
(5) Intensification strategy, which aims at modifying the epistemic status of a proposition and is realised through devices that intensify or mitigate the illocutionary force of utterances.

To perform the last step of the CADS, the concordances for each theme were read and analysed according to these discursive strategies, which we have translated into our five research questions: (1) how are elderly persons named and referred to linguistically in Swedish media? (2) Which nouns, adjectives, verbs and adverbs are attributed to them? (3) By means of which arguments are discrimination and suppression expressed? (4) From which perspective or viewpoint are these arguments expressed? (5) Are the respective utterances intensified or are they mitigated?

In the analysis, we read the words closest to the node in each theme to achieve a deeper and contextualized understanding of the material and attempted to answer the research questions. The following section presents the results from our analysis. In our analysis, we organized our collocates into themes based on the discursive strategies that correspond with our abovementioned research questions.

4. Results

The presentation of our results follows the three analytical stages of CADS: first, we provide a descriptive presentation of the node 'elderly' in the COVID-19 corpus, then the identified and analysed collocations are described, and, lastly, the analysis of the results from the concordance analysis are presented.

4.1. Frequency of 'Elderly' as a Node in the Investigated Corpus

In our corpora consisting of articles that include the word COVID-19 published in three daily newspapers during 2020, the node being investigated is 'elderly'. If we examine the occurrence of this node, the distribution is similar to the distribution of the total number of articles that mention COVID-19 (see Figure 1). It was not until March 2020 that the node occurred, but the number of occurrences increased rapidly and the reporting peaked in April 2020, with 2532 mentions of the node. During the summer months, the node

occurred less frequently; however, during autumn, the occurrence of the node increased again and there was a second smaller peak in November 2020. This implies that the node 'elderly' was mentioned frequently in the articles that covered the pandemic. It is, of course, possible that one article may have several references to the elderly and another article may have none; nevertheless, 'elderly' is an important node in the reporting on COVID-19 in Swedish mass media during the year 2020.

The relative frequency of the node in relation to the number of times COVID or COVID-19 occurs in the corpus was greatest during the peaks—April–May and November–December—and least during the summer months. The peaks in the occurrences corresponded to the two waves of infection in Sweden during 2020, which indicates that not only did a relatively large proportion of the corpus include the node but also that the mentioning of the elderly in mass media reporting followed the two waves of COVID-19 infections.

4.2. Collocations: Words That Co-Occurring with the Node 'Elderly'

Here, we turn to the second step in CADS: a collocate, or co-occurrence, analysis. We used a log-likelihood procedure as the statistical measure to analyse which other words appeared in close relation to the node 'elderly'. We have used the 20 most frequent collocations to present the most prominent discourses regarding the elderly in the context of the pandemic.

Table 1 presents the collocations of 'elderly'—first, the rank of the word, with the first word having the rank of 14. Words without discursive meaning in the context have been deleted from the table, thereby leaving only meaningful words in the analysis. The next column presents the frequency of the word and then how many times the word appears before the term 'elderly' (left of the search term) and how many times the word appears after the word (right of the search term). The threshold for an α-level of 0.05 is a log-likelihood stat of 3.8 [44] (p. 209), thereby implying that the risk of the collocation occurring by chance is very small with stats higher than 1000. Further, the last two columns present the collocation in the original language (Swedish) and the translated word in English.

Some words can easily be considered as merely terms that describe the elderly without adding any valuable information. 'Persons' and 'people' are used along with 'elderly'; moreover, 'elderly persons', 'elderly people' and the word 'COVID' do not add anything since the entire corpus addresses COVID-19 and Corona. After eliminating these words marked with an asterisk (*), 17 signifying words remain, in Table 1. The collocates are single words and to signify the meaning of the collocates; we need to dig deeper into the material by using the context around the single words—that is, the concordances.

4.3. Concordances: Contextualisation of the 'Elderly' Node

In the analysis of concordances, we turn to the discursive strategies of DHA [12], as previously described. The first step for our analysis was to organise the 17 remaining collocates from the perspective of how they appeared in the concordances in relation to the discursive strategies presented earlier; the result of that analysis is presented in Table 2 below.

Table 2. Categorisation of collocates according to discursive strategies and thematic concordances.

Discursive Strategy	Categorisation of Collocates	Thematic Concordances
Referential strategy	Sweden, our, the country's	The discursive construction of an in-group
Prediction strategy	Ill, fragile	Stereotypical representations
Argumentation strategy	Protect, risk groups	Political inclusion/exclusion
Perspectivation strategy	Accommodation, accommodated, homecare, care, personnel, visitors, visitor curfew, relatives, infection	Perspectivations and discursive devices
Intensification strategy	A concluding and total reading of the meaning produced	

4.3.1. Referential Strategy: How Are Elderly Persons Named and Referred to Linguistically in Swedish Media?

With regard to the referential strategy, the elderly were referred to using collocates, such as 'Sweden's, 'our' and 'the country's' elderly, which can be interpreted as discursive constructions of a national in-group. Table 3 presents typical collocates that represent 'Sweden', 'our' and the country's'. 'Our' elderly is often used to describe the elderly in the corpus and belonging to 'Sweden' or 'the country'. It is a clear in-group reference where referential strategies are used, such as the country's elderly, our elderly, the elderly in Sweden, etc. This group is also 'ours' in the sense that they need protection and our help within the framework of Swedish society. The material emphasizes how the elderly in Sweden must be protected or how Swedish society has failed to protect 'our' elderly, particularly in nursing homes. Note that the Swedish model for elderly care is strongly criticized as it has not been able to protect the elderly from infection.

Table 3. Categorization of collocates according to referential strategies.

Collocates	Illustrative Example of Concordance
Our	Municipalities to cut further on their elderly care. Society's debt to our elderly is enormous.
The country's	It is obvious that Sweden has let down the country's elderly. It has both the Prime Minister and the public health authority
Sweden	Should be able to wrap a protective ring around our sick and elderly in Sweden in corona times.

In the Swedish context, the invoking of 'our', 'Swedish' and the 'country's' elderly could also be interpreted based on what Barker [45] terms the duality of the Swedish welfare state, referring to its simultaneously inclusionary and exclusionary character. Sweden leans towards 'welfare nationalism', which is a form of protectionism in terms of the welfare system that involves desperately trying to sustain it by excluding others or making it difficult for them to belong [44] (p. 17). Barker [45] explains that, in Sweden, there is a pattern of excluding people who are considered 'undeserving'. As this practice has been questioned as part of the pandemic debate on whether the elderly are deserving or, as indicated in previous analysis, disposable in the struggle for herd immunity [3].

The referential strategy employed in our corpus could be understood as a strategy towards the discursive construction of an in-group, which we as individuals and Swedish society at large are responsible for caring about. Thus, the inscription of value in the elderly considers their past efforts, as 'our elderly' is a term constructed to include those who have previously contributed to society and, therefore, society has a debt to pay to them. The use of words such as 'our elderly' and 'the country's elderly' can evoke thoughts with a clearly nationalistic focus by portraying the Swedish elderly as people who built the country. This discursive device makes it possible to pit groups against each other and raise a question regarding the elderly who do not belong to the category of 'ours'.

4.3.2. Prediction Strategy: Which Nouns, Adjectives, Verbs and Adverbs Are Attributed to the Elderly?

With regard to the prediction strategy, the elderly were depicted as 'ill' or 'fragile', which is a rather stereotypical representation of the elderly as vulnerable, weak, ill and vulnerable to infection. Table 4 illustrates this with examples of concordances, including 'fragile' and 'ill'. 'Fragile' is used both to describe the state of elderly people as well as to describe that elderly and other fragile people must be protected during the pandemic. This word is often found in the context of describing the goal of the Swedish strategy—'to protect the fragile and elderly'. Thus, the elderly are described as a homogeneous group that is vulnerable and in need of protection. The context is the spread of COVID-19 to nursing homes and then the rapid spread among residents, which led to many elderly people becoming ill and a few dying. Thus, the image of the elderly is greatly simplified and unidimensional.

Table 4. Categorization of collocates according to prediction strategies.

Collocates	Illustrative Example of Concordance
Fragile Ill	Deals with the fact that an awful lot of elderly and fragile people have been swept away, probably in general, those who become seriously ill and require intensive care are the elderly and preferential

Moreover, the homogenous nature of the elderly category is problematic because it makes it easier to portray the elderly as a homogenous group. Collocating the term with words such as fragile and ill is the result of an ageist discourse [19]. The word 'fragile' was used to describe the state of the elderly as well as convey the idea that the elderly and other fragile people must be protected during the pandemic. It was often used when describing the goal of the Swedish strategy, which is to protect the fragile and elderly. As previous studies have shown, the word 'ill' has also been used in the context of the COVID-19 pandemic, since this disease primarily affects the elderly [5].

4.3.3. Argumentation Strategy: By Which Means Are Arguments of Discrimination and Suppression Expressed?

The argumentation strategy was used in relation to the 'elderly' node in our corpora and associated with words such as 'protect' and 'risk groups', which we interpreted in terms of inclusion and exclusion in the political landscape (see Table 5). These words appeared in concordances that were focused on the need to be cared for and protected. In other words, the Swedish strategy was based on the goal of protecting the elderly (who were often referred to as 'our elderly') and the debate centred around whether Sweden has succeeded in doing so. Elderly people are also portrayed as being without their own ability to act, although they must instead be helped and taken care of by society. The elderly have helped to build the country, but now that the corona epidemic is threatening their health and lives, we must hurry to their rescue. The elderly are worthy of our care but, simultaneously, are deprived of the opportunity to act independently; however, they are often described in the same way as children, as those who must be protected and taken care of but are not full-fledged members of society.

Positioning the elderly as a risk group to be protected can be considered as a form of political inclusion; however, it can also be seen as a means to turn them into a group that needs to be governed or is legitimate to govern. In accordance with Skoog [5], we understand that formulating the elderly as the primary 'at risk group' can have implications on the measures that are possible to implement. For example, in Sweden, elderly focused restrictions were implemented, such as visitor curfews at nursing homes.

Table 5. Categorization of collocates according to argumentation strategies.

Collocates	Illustrative Example of Concordance
Protect	The Swedish strategy of protecting the elderly has failed. The Commission notes that
Risk groups	during the COVID pandemic, the strategy has been to protect the elderly and other risk groups from becoming infected. To
	protect risk groups as much as we can, particularly the elderly. They can be affected really badly.
Visitor curfew	Since April 1, a national visitor curfew has applied to the country's elderly nursing homes.

4.3.4. Perspectivation Strategy: From What Perspective or Viewpoint Are These Arguments Expressed?

Many of the words that create the context for the 'elderly' node describe aspects of institutionalised care, such as special nursing homes, home care, personnel, visits and relatives (see Table 6). These words can be understood through a perspectivation strategy, which refers to a perspective from the speaker's perspective. Although the critique is of a more general political character, the framing of nursing homes and elderly care produces a negative image of institutional elderly care.

Table 6. Categorization of collocates according to perspectivation strategies.

Collocates	Illustrative Example of Concordance
Nursing homes	Almost every second person who died of COVID-19 in Sweden lived in nursing homes for the elderly. Skåne has done well
Home care	The deaths are mostly those of the elderly in nursing homes or home care
Care	COVID-19 has made visible major shortcomings in elderly care. Sweden can do much better than this
Personnel	COVID testing was not carried out on personnel in nursing homes for the elderly until after the infection culminated
Visit	of the risk of spreading. Many municipalities advise against visits to the elderly and to special accommodation
The infection	Disappointed with the municipality that they let in the infection. They should have closed the elderly nursing homes immediately
Relatives	Municipalities did not inform the authorities about the virus in specific elderly nursing homes, which created concern among relatives, but the National Board of Health and Welfare can

When reading the concordances in context, it is evident that these sentences are often embedded in a narrative regarding the large number of deaths among the elderly in nursing homes along with either the failure of the Swedish pandemic strategy or the historical governance of elderly care. The perspectivation strategy made it possible to question and criticize elderly care from the perspective of the relatives and friends. This reveals how the framing of the pandemic in relation to institutional elderly care was used to illuminate the deficient structure and organisation of such care, including financial shortages and the large number of personnel without professional training and that are on temporary employment contracts and move among elderly homes. Personnel, nursing homes, home care and visitors were then framed as posing infection risks to the elderly. Thus, the elderly were constructed as an at-risk group, while visitors, personnel and nursing homes were constructed as risky or a threat to the elderly.

5. Discussion: Intensification Strategy

In the present study, we used a combination of corpus linguistics and discourse analysis, based on corpus assisted discourse studies (CADS) [40], to identify constructions of the elderly in Swedish mass media coverage of the COVID-19 pandemic during the year 2020. In this last discussion section, we summarize the results and discuss the intensification strategy. The intensification and mitigation strategies concern how the epistemic condition of the elderly and others are emphasized or softened in the corpus [37]. As mentioned in the introduction, in the spring of 2020 it became evident that Sweden had failed to protect its elderly, mainly because it had de-prioritised elderly care for a long time [7,8]. Our results confirm that the word 'elderly' was frequently mentioned in articles on COVID-19 in 2020, particularly during the spring. The pattern was the same in all three studied newspapers, thereby indicating homogeneity in news reporting during the period under investigation.

Our aim with this study has been to explore the discursive formations of the elderly in Swedish media during the pandemic and how these formations relate to risk and the discursive constructions of in- and out-groups. Through our analysis thus far, we have showed that that the elderly were labelled and referred to through the perspective of Swedish welfare exceptionalism, in which their in-group position is emphasized through focus on being 'ours'. When comparing this with previous studies, it is also possible to read this referential strategy as a means for journalists to re-inscribe value into the category of elderly who are perceived to be sacrificed in the struggle for herd immunity [3]. This tendency appears to be less evident in studies of the framing of elderly in media reports during the pandemic outside Sweden. Although it might not be intentional, this rhetoric has also opened up for a pitting of groups against each other, where, for example, our elderly must be safeguarded before or instead of other vulnerable groups, such as immigrants.

With regard to the nouns and adjectives attributed to the elderly, our study revealed that it was a rather stereotypical and homogenous framing of the elderly as vulnerable, weak, ill and exposed to infection. This result conforms to those of previous studies both

within and outside of Sweden, and as these studies have already stated that such framing performs both explicit and implicit ageism [17,19,21]. By means of which arguments is this discrimination and suppression expressed? The positioning of the elderly as a risk group to be protected is considered a form of political inclusion; simultaneously, it is a means to turn them into a group that needs to be governed or is legitimate to govern. This benevolent form of ageism was manifested in the Swedish context through the specific restrictions that were developed for people aged above 70 years and their care homes. The perspectivation strategy present in our corpus reveals how the pandemic made it possible to question and criticize elderly care from the perspective of relatives and others and, as has also been indicated in other studies, to discuss major problems with institutional living [20]. Personnel, nursing homes, home care and visitors were then framed as posing infection risks to the elderly.

Now, what is remaining is to answer the question regarding whether the respective utterances are intensified or mitigated. In studies similar to ours, it is revealed that the media communication on the COVID-19 pandemic employs ageist language and ageist stereotypes to characterize the elderly [19,21]. Thus, the management of the pandemic caused a mental construction of the elderly as being fragile and as almost the only ones who could become ill due to the virus [5]. The Swedish public debate in the spring of 2020 mirrored this focus on restrictions for the elderly and other risk mitigation actions that the government and the Swedish Public Health Agency implemented at the time [15]. Considering this stereotypical formation of the elderly in the corpus, we see this as an intensification strategy which modifies the understanding of the elderly in society. However, as such, the discursive formulation of the elderly as an in-group, 'our elderly', also works as a device to strengthen the definition of 'us' and those who belong in Swedish society. This language of risk was entangled with positions of subordination associated with age, and, as a subject, one tends to act according to performative risk discourses, as the work of normalisation processes [33]. The normalised understanding of old age as a manageable risk [36] was confirmed and enhanced during the pandemic. Thus, to better understand vulnerability management and resilience under disasters, we need to investigate how common social groups, such as the elderly, are constructed in terms of risk in the public debate. We attempted to disentangle the manner in which the performativity of risk is intertwined with the processes by which age is constructed within a system and through which risk discourses can be mobilised and used to uphold other formations. The elderly were normalized as ill and in need of protection—that is, an at-risk group—and this was considered natural and taken for granted [16,37]. We found similar patterns as those found by Zinn and MacDonald [11] in their study of how risk reporting in print news media has shifted towards a greater emphasis on what they call 'everyday social groups'—for example, women, the elderly and children—but with the display of less agency in the linguistic expressions related to the elderly. Thus, the elderly were also homogenised, as we did not find any examples in our collocates where the elderly category was non-homogenised or deconstructed, at least not in any of the concordances that we read.

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Integration of GIS-Based Multicriteria Decision Analysis and Analytic Hierarchy Process for Flood-Hazard Assessment in the Megalo Rema River Catchment (East Attica, Greece)

Efthimios Karymbalis [1,*], Maria Andreou [1], Dimitrios-Vasileios Batzakis [1], Konstantinos Tsanakas [1] and Sotirios Karalis [2]

[1] Department of Geography, Harokopio University, GR-17671 Athens, Greece; mandreou@hua.gr (M.A.); mpatzakis@hua.gr (D.-V.B.); ktsanakas@hua.gr (K.T.)
[2] Department of Surveying and Geoinformatics Engineering, School of Engineering, University of West Attica, GR-12243 Athens, Greece; skaralis@uniwa.gr
* Correspondence: karymbalis@hua.gr; Tel.: +30-210-954-9159

Abstract: This study deals with the flood-hazard assessment and mapping in the catchment of Megalo Rema (East Attica, Greece). Flood-hazard zones were identified utilizing Multi-Criteria Decision Analysis (MCDA) integrated with Geographic Information System (GIS). Five factors were considered as the most influential parameters for the water course when high storm-water runoff exceeds drainage system capacity and were taken into account. These factors include slope, elevation, distance from stream channels, geological formations in terms of their hydro-lithological behavior and land cover. To obtain the final weights for each factor, rules of the Analytic Hierarchy Process (AHP) were applied. The final flood-hazard assessment and mapping of the study area were produced through Weighted Linear Combination (WLC) procedures. The final map showed that approximately 26.3 km^2, which corresponds to 22.7% of the total area of the catchment, belongs to the high flood risk zone, while approximately 25 km^2, corresponding to ~15% of the catchment, is of very high flood risk. The highly and very highly prone to flooding areas are located mostly at the southern and western parts of the catchment. Furthermore, the areas on both sides of the channel along the lower reaches of the main stream are of high and very high risk. The highly and very highly prone to flooding areas are relatively low-lying, gently sloping and extensively urbanized, and host the densely populated settlements of Rafina-Pikermi, Penteli, Pallini, Peania, Spata, Glika Nera, Gerakas and Anthousa. The accuracy of the flood-hazard map was verified by correlating flood events of the last 30 years, the Hydrologic Engineering Center's River Analysis System (HEC–RAS) simulation and quantitative geomorphological analysis with the flood-hazard level. The results of our approach provide decision makers with important information for land-use planning at a regional scale, determining safe and unsafe areas for urban development.

Keywords: Multi-Criteria Decision Analysis; AHP; GIS; flood-hazard; Megalo Rema; Eastern Attica

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1. Introduction

Floods are among the most frequent and dangerous natural hazards and the leading cause of natural disaster fatalities worldwide [1]. They represent approximately one-third of all global hazardous events, and the number of extreme flood incidences has significantly increased over the past few decades [2]. Every year this type of hazard causes a significant loss of life and property [3] and severely affects the natural and human environment as well as the development of an area [4].

Floods in urban and peri-urban areas are caused by the complex combination of both natural and human-induced factors [5,6]. Among the most important physical factors are extreme precipitation events and the "organization" of the drainage network, as well as the geological and geomorphological conditions of the catchment [7]. Moreover, human

causes of flooding include rapid urbanization. Urbanization results in a decrease in surface permeability, caused by the coverage of the surface with materials (such as concrete and asphalt) which decrease infiltration and at the same time increase surface runoff. Population growth, uncontrolled building construction and lack of urban planning can disturb the drainage system function by blocking or modifying the water flows in stream channels. Similarly, deforestation and poor land use practices lead to a decrease in infiltration [8,9].

Climate predictions reveal that the number and the severity of extreme precipitation events seem to increase despite the reduction in total annual and seasonal rainfall [10]. At the same time, rising urbanization and economic development negatively affect hydrological processes, causing floods in areas of the catchment where they would not occur under normal circumstances. The combination of the aforementioned facts is expected to make river floods more frequent, intense and damaging in terms of human casualties and financial losses [11–13]. Therefore, there is an increasing demand for flood risk management policies for the protection of human communities in urban and peri-urban areas.

Flood risk management is the operation of corrective and preventative measures for reducing flood damage and includes four phases, namely: mitigation, preparedness, response and recovery. It is obvious that flood management strategies and action plans at a catchment scale require the identification and classification of flood-prone areas [14]. Flood-hazard assessment along with flood-hazard mapping is an essential step to identify potential flood-hazard areas under extreme rainfall events. Flood-hazard assessments conducted through easily read and rapidly accessible charts and maps aid in the identification of areas at risk of flooding. Hazard maps can also be adopted in land use and development planning, as part of a holistic approach for flood preparedness that can promote future land developments and community awareness. In addition, flood-hazard mapping can help prioritize mitigation and response efforts in order to decrease the impact of possible flood events in the future [15–17].

Multi-Criteria Decision Analysis (MCDA) is a decision-making tool developed for the solution of complex-decision problems. In the case where a plethora of criteria are involved, confusion can arise unless a logical and well-structured decision-making process is followed [18]. After the criteria are ranked according to their relative importance, the weight of each criterion is usually defined following the Analytical Hierarchical Process (AHP). AHP is a semi-quantitative, flexibly structured technique designed for hierarchical representation of a decision-making problem, where a large number of interrelated objectives or criteria are involved [19,20]. Geographic Information System (GIS) is, similarly, an important tool which provides the capacity to design geospatial identities and analyzes and manipulates spatial information. This information can be managed and organized through attribute tables. The tabulated data, which are linked to geographic features, can contain qualitative and quantitative information. Calculations can be conducted to reveal spatial trends and relationships between overlaid data, retrieving important information for decision making [21]. The results can be visualized and presented via maps. MCDA, when integrated with Geographic Information System (GIS), results in GIS-based MCDA, which is one of the most useful and robust methods that combines and converts the input criteria map layers into a final map that is a spatial decision tool, and very useful for policy makers [18,22]. GIS-based MCDA methods along with AHP have become quite popular for spatial planning and management issues. Such approaches are also quite common in the geoscience fields, such as landslide susceptibility analyses [23,24], landscape neotectonic deformation assessment [25,26] and soil erosion [27], as well as in flood-hazard assessment studies [15,28,29]. Approaches that combine the use of GIS-based MCDA in flood-hazard assessment were applied in urban areas in Belgrade, Serbia [30], in arid and semi-arid areas in Riyadh, Saudi Arabia [31], in the coastal area of Maharashtra, India [32] and in the fast-urbanizing area of Eldoret Municipality in Kenya [33].

In Greece, several researchers use GIS-based MCDA methods to assess potential flood-prone areas, e.g., in Kassandra Peninsula (northern Greece) [34], in Rhodope-Evros region (northern Greece) [15], in Thessaly (central Greece) [35], in northeastern Peloponnese

(southern Greece) [36] and in the drainage basin of the Pinios River (western Greece) [37]. Additionally, GIS-based MCDA methods have been applied for flood-hazard assessment and mapping in the broader Attica Region [38], in the metropolitan urban area of Athens, the capital of Greece [8], as well as in the burned urban area of the northeastern part of Attica Prefecture [17].

This paper aims to assess and map the flood-hazard in the catchment of the Megalo Rema River, a flood-prone peri-urban area in the greater southeast Mesogeia region of Eastern Attica, Greece. For this purpose, a methodology based on the application of a GIS-based MCDA was conducted and applied for the first time in this study area. The GIS-based MCDA involved various factors such as slope, distance from stream channels, land cover, elevation and geology, which were selected by the experts as the most critical factors contributing to flood-hazard. The weight of each factor/criterion was defined following the AHP [39,40] after they were ranked according to their relative importance based on the experts' experience in flood-hazard analysis. Morpho-climatic characteristics of the basin were also taken into account. Thus, this study tries to address the implications of GIS-based MCDA on flood-hazard assessment by setting the factors influencing the specific basin and the determination of the pairwise importance values in a different manner from other similar studies. Flood-hazard assessment and mapping lead to the identification of areas at risk of flooding, and consequently provide a tool for the improvement of flood risk management and disaster risk reduction actions in the study area.

2. Study Area

The Megalo Rema River, located in East Attica, Greece, is an ephemeral stream and drains an area of approximately 115 km^2 (Figure 1). The drainage basin reaches a maximum elevation of 950 m at its northeastern border (Penteli Mt.). The catchment includes the residential areas of the Rafina, Pikermi, Ntaou Penteli, Pallini, Gerakas, Anthousa and Glika Nera regions with a total population coverage of ~117,000 residents. The sixth order (according to Strahler's [41] ordering system) main stream channel has a length of 25 km and follows a WSW–ENE flow direction. It discharges into the South Evoikos Gulf where the town of Rafina is located, with a population of ~13,000 inhabitants.

In the asymmetric Megalo Rema basin the drainage system is well developed north of the main channel, whereas to the south a few channels of low order exist (Figure 1) [42]. The catchment can be divided geomorphologically into two areas: (a) the relatively mountainous northern part of rough relief consisting mainly of metamorphic rocks (schists and marbles) from the Mesozoic age belonging to the autochthonous Almyropotamos geotectonic unit, and (b) the southern area of lower elevations, gentle slopes and a generally smoother relief that is composed mainly of lacustrine marls, silts, marly limestones and conglomerates of the Upper Miocene age [43,44].

The climate of the study area is typically subtropical Mediterranean, with prolonged hot and dry summers succeeded by considerably mild and wet winters. The mean annual precipitation ranges from 362 mm at the mouth of the river to 473 mm in the SW part of the catchment at Mount Ymittos, while the mean annual air temperature is 17.2 °C. The rainy period begins in October and ends in March.

The Megalo Rema drainage network is part of the GR06RAK0003 potentially significant flood risk (PSFR) zone, which was defined by the Greek Special Secretariat for Water (SSW) [45] under the European Council (EC) Floods Directive 2007/60/EC [46]. The Megalo Rema catchment is an area greatly prone to flash flooding. It is estimated that over the last twenty-seven years, one flash-flood event occurred every 2.7 years [47]. In addition, more than thirty-two flood events have affected the area between 2004 and 2014, with eighteen of these characterized as significant flood episodes based on the hydrological response intensity of the study catchment. The application of a system based on the coupling between the Weather Research and Forecasting (WRF) numerical weather prediction model and its hydrological extension package (WRF-Hydro) by Giannaros et al. [48] showed that the majority of the flash flood events in Megalo Rema catchment took place during the

wet period of the hydrological year and were associated with typical, for the study area, wet-season cyclonic activity [49]. This is due to the global atmospheric circulation during the autumn and winter, which interacts with the complex geomorphology and land-sea temperature contrast in the Eastern Mediterranean region, favoring the development of cyclonic atmospheric conditions [50]. In particular, the flood episodes of the study area were driven by low-pressure systems, which, in most cases, affected the catchment while moving from the west towards the east [49]. However, the recent extreme flood events in Europe, caused by an abnormality in cyclonic seasonal activity, show an increase in rainfall intensity and a rise in frequency of flood rates due to climate change [51]. In Greece, even though the precipitation levels are predicted to decline an average of 17% annually, the flood hazard is expected to rise, thus increasing the cost of direct damage from floods up to 10% annually [52]. This means that flood rates and the period of occurrence of past events may not be reliable in the future due to climate change. Moreover, large wildfire-burn territories, increased urbanization, mild topographic slopes and the absence of efficient inundation protection make the catchment greatly prone to flash-flooding [42,49].

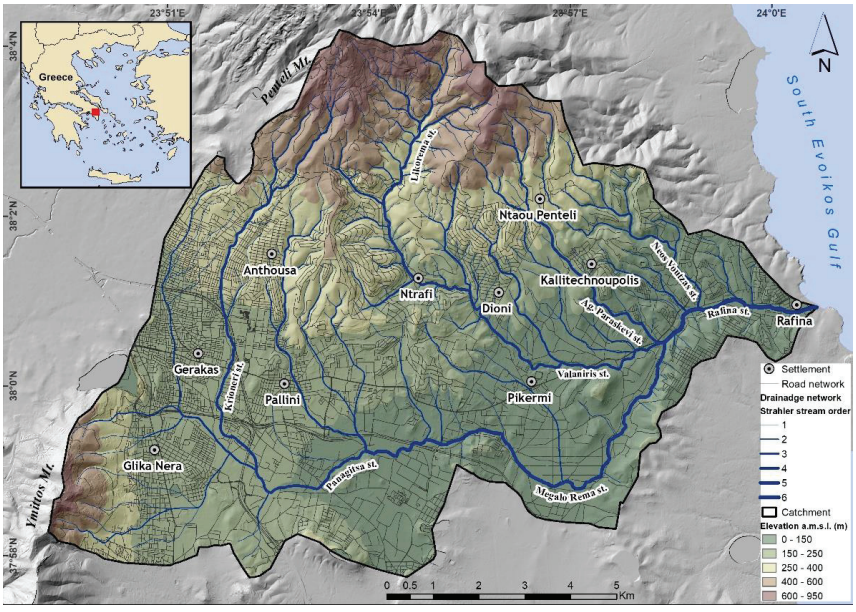

Figure 1. Shaded Digital Elevation Model map of the Megalo Rema drainage network and catchment. Inset map shows the location of the study area.

3. Materials and Methods

3.1. Flood-Hazard Criteria

For the flood-hazard assessment, a GIS-based MCDA was implemented (Figure 2). The analysis was based on five factors relevant to flood-hazard as documented in the literature [53]. The selected factors include slope, elevation, distance from the channels of the higher order streams, hydro-lithological characteristics of the geological formations and land cover. These factors control the water route when drainage system capacity is exceeded by high runoff and have been proved effective when included in flood-hazard assessment studies and applications [8,15,17,38].

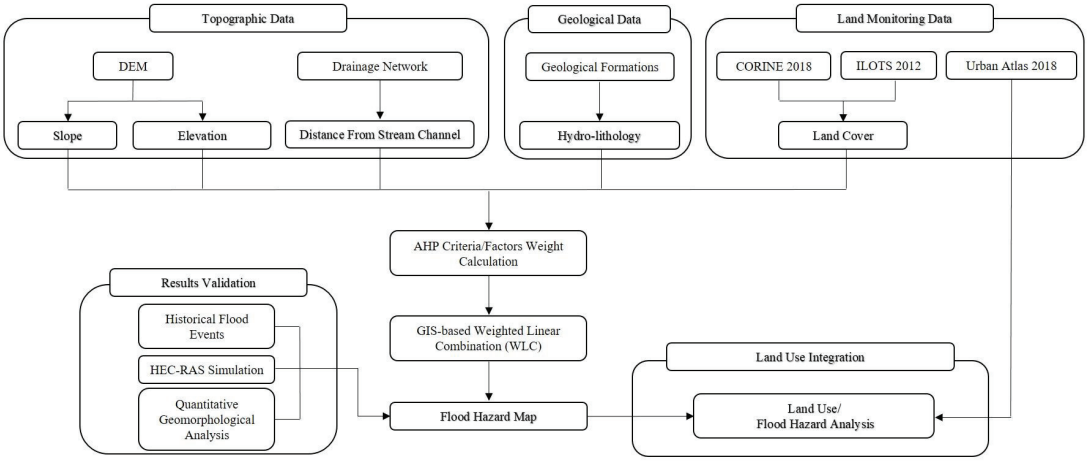

Figure 2. Flow diagram of the methodology for the present study.

A crucial step in the flood-hazard assessment methodology was the classification of all of the factors. Hence, each factor was divided into classes with specific boundary values. The classes of the involved factors have to be standardized to a uniform suitability rating scale. The standardization method used in the analysis was consistently based on a five- and three-grade scale, according to the hazard level each criterion contributes to the total flood-hazard. Integer numbers, ranging from 0 to 4 and 1 to 3, were assigned to every class of the five- or three-grade scaled criteria, respectively. The class which was rated as 0 represented no hazard level whereas the one rated as 4 represented a very high hazard level. Thus, each of the five factors involved in the flood-hazard assessment is represented by a spatial distribution map of the classified values, reclassified to a regular scale, and then by a thematic map of the spatial distribution of the standardized values.

3.1.1. Slope

Surface runoff and the water accumulation process in any geomorphic setting relies upon its surface slope appropriation [54]. Water flows from higher to lower elevations, which therefore means that slope influences the amount of surface runoff and infiltration. Flat and gently sloping areas (0–18°) in low elevations are more prone to flooding [55]. In these areas, the surface water runoff is usually accumulated easier and, as a result, intense precipitation can flood these low-slope areas faster than areas in higher elevation with a steeper slope.

The slope of the study area was computed utilizing ArcGIS/ArcMap ESRI® by inputting elevation data derived from the detailed 5 m resolution DEM of the catchment, obtained from the Hellenic Cadastre (Ktimatologio S.A.). The resulting slope map consists of a 5 m resolution raster layer which was then converted to a vector layer, which represents the steepness of the terrain of the study area in degrees. The slope values were classified into five classes, based on the correlation of the slope with previous flood events. The classes were assigned a value from 0 to 4. Therefore, the gently sloping parts ($\leq$2°, 2–6°, and 6–12°) of the catchment are considered as prone to flooding areas and were assigned the rating of 4, 3 and 2, respectively (see Table 4). Steeper parts of the area with a slope between 12 and 20° and >20° were assigned the ratings of 1 and 0.

3.1.2. Distance from Stream Channels

River-overflows are crucial for the initiation of a flood event. According to Predick and Turner [56], proximity to the stream channel critically increases the possibility of experiencing a riverine flood event. During extreme rainfalls, high discharges often cause a

rapid rise in river level, leading to an overflow of water from the riverbed and inundating the surroundings. Hence, regions situated near rivers endure frequent flooding [57]. In contrast, areas far from stream channels generally have a lower probability of flooding, since the likelihood of being within the flood-induced riverbed is lower.

Areas near the stream channels are considered to have a high flood-hazard, whereas the effect of this parameter decreases with distance from the channels. It is obvious that there is no universal agreement on the critical distance that can have higher susceptibility, and this distance changes from river to river. In this study, the distance from the stream channel was taken into account in an analogical manner, by comparing the distances which were used in similar studies in correlation with the catchment size (see [8,15]).

The drainage network was acquired from the 1:5000 scale topographic maps of the Hellenic Military Geographical Service. This factor was calculated by imposing buffer zones within the ArcMap interface, by creating polygons enclosing the area on either side of the higher order stream channels, for each given distance from the channel. Records of historical floods in the study area [49] as well as the results of the simulation of the river hydraulics' behavior—using the Hydrologic Engineering Center's River Analysis System (HEC–RAS) developed by U.S. Army Corps of Engineers Hydrologic Engineering Center in GIS Environment—for the last 4 km before the river mouth [47], were particularly useful in defining the classes of this criterion. For the third order stream channels of the drainage network, 10, 20, 30, 40 and >40 m buffer zones were generated. Around the fourth order stream channels, buffer zones at the distances of 15, 30, 45, 50 and >50 m were created. For the fifth order streams, buffer zones at distances of 20, 40, 60, 80 and >80 m from the channels were considered, whereas buffer zones at the distances of 25, 50, 70, 100 and >100 m from the sixth order main channel of Megalo Rema were imposed. The shorter the distance, the higher the hazard level and the assigned value, and the longer the distance, the lower the hazard level and the assigned value.

3.1.3. Land Cover

Several hydrological processes such as surface runoff, infiltration rate and evapotranspiration, as well as interrelationship between surface and groundwater, are being significantly controlled by the land cover pattern of an area. As a result, land cover is considered an important parameter in flood-hazard assessment [58].

An integrated land cover layer of the drainage basin was created by the information obtained from CORINE Land Cover (CLC 2018) of Copernicus Land Monitoring Service and Agricultural Blocks (ILOTS 2012) of the Ministry of Rural Development and Food. The land cover type was classified into five categories: (i) densely urbanized areas, (ii) sparsely urbanized areas, (iii) agricultural land, (iv) land covered by sparse vegetation and (v) forests. Densely and sparsely urbanized areas that support the overland flow of water were assigned the highest ratings of 4 and 3, respectively, whereas forests have been assigned the lower rating of 0 since they favor infiltration.

3.1.4. Elevation

According to several relevant research studies and applications, elevation is one of the dominating factors that control flood occurrence [59–61]. Because of the gravitational force, water moves rapidly from upland to lowland areas and the water gets spread over the lower elevated plains, causing inundation [62]. However, it is not possible for a widely agreed flood elevation threshold to be set due to the various morphological/morphometric characteristics of each catchment. The relationship between elevation and flood events in the Megalo Rema catchment shows that almost 82% of the past events occurred in elevations lower than 200 m, while areas of elevations higher than 500 m have not been affected by floods.

The elevation grid of the study area was produced by the 5 m resolution DEM, and elevation values were divided into five categories by evaluating the elevation of the historical flood events in the study area catchment. The low-lying areas, with elevation

≤50 m, were assigned the highest rating 4, since they were considered as more prone to flooding.

3.1.5. Geological Formations

The hydro-lithological characteristics of the geological formations of an area are an important criterion, because they may amplify or extenuate the magnitude of flood events. The presence of permeable formations favors water infiltration while impermeable rocks favor surface runoff.

The geological formations of the catchment were derived from the corresponding 1:50,000 geological map of the Institute of Geology and Mineral Exploration [43,44], and were classified according to their hydro-lithological behavior into three categories: permeable, semi-permeable and impermeable. Permeable geological formations include tectonically fractured and karstified limestone and marbles, sandstones and alluvial deposits [63,64]. Marls, conglomerates and silts are considered semi-permeable formations while schist is considered impermeable rock, since the fine-grained material produced by their weathering blocks their fracture system [63]. Higher rating 3 has been assigned to impermeable geological formations due to their lower infiltration capacity.

3.2. Analytical Hierarchy Process (AHP)

The final weights of each factor were defined following the AHP [39,40]. The first step in the AHP was the computation of the pair-wise comparison matrix, where each entry represents the relative significance of each factor/criterion to the others. The method of comparisons per pair is the most commonly used process for the calculation of criteria weight coefficients. AHP is based on the allocation of weights to the criteria used, according to their importance. The relative importance between two factors was measured according to a numerical scale from 1 to 9. The correlation between the numerical values and the intensity of importance was as follows: 1 = equal, 2 = weak or slight, 3 = moderate, 4 = moderate plus, 5 = strong, 6 = strong plus, 7 = very strong, 8 = extremely strong and 9 = of extreme importance. Inversely, less important variables were rated between 1 and 1/9 [19,20]. Completion of the degree of significance between two factors requires field experience, knowledge of the subject and/or the opinion of the experts, who assign the value a_{ij} according to their judgment for the relative importance of one criterion over the other [65]. If a criterion has equal importance with the one it is being compared with, then the preference value (a_{ij}) is equal to one. If the relative importance of a criterion is higher than the criterion it is being compared with, then $a_{ij} > 1$ and the reciprocal property is $a_{ji} = 1/a_{ij}$. When comparing a criterion with itself, the assumption is that $a_{ii} = 1$ for all the n criteria. In this way, a preference table is created (Table 1).

Table 1. Pairwise comparison matrix of the criteria (preference value: $a_{ij} = w_i/w_j$, where w_i/w_j is the relative importance of factor i to factor j).

a_{11}	a_{12}	...	a_{1n}
a_{21}	a_{22}	...	a_{2n}
	...		
a_{n1}	a_{n2}	...	a_{nn}
Sum_1	Sum_2	...	Sum_n

After assigning the preference values (α_{ij}), the columns of Table 1 are summed to Sum_j and then the preference values of each column (α_{ij}) in Table 1 are divided by the sum of the corresponding column (Sum_j) and the values are summed again, in rows this time (Row_sumi) (Table 2). Finally, the set of each line (Row_sumi) is divided by the number of variables (n) and the result equals the weighting coefficient (W_i) of each criterion.

Table 2. Preference values (a_{ij}) are divided by the column Sum_i (aij/Sum_j), sum of matrix rows (Row_sumi) and calculation of the weights (row sum divided by n) (Weighting coefficient (Wi)) [66].

a_{ij}/Sum_j				Row_Sumi	Weighting Coefficient (Wi)
a_{11}/Sum_1	a_{12}/Sum_2	...	a_{1n}/Sum_n	Row_sum1	Row_sum1/n
a_{21}/Sum_1	a_{22}/Sum_2	...	a_{2n}/Sum_n	Row_sum2	Row_sum2/n
	...				
a_{n1}/Sum_1	a_{n2}/Sum_2	...	a_{nn}/Sum_n	Row_sumn	Row_sumn/n

AHP requires normalization of all factor weights, which was achieved using the following equation:

$$\sum_{i=1}^{n} W_i = 1 \quad (1)$$

After the calculation of the weight values, it is important to verify the consistency of each table matrix. The implication of each one was checked with the Consistency Ratio (CR). This ratio is used to avoid the creation of any incidental judgment in the matrix. When CR < 0.1, an acceptable level of consistency has been achieved, while judgments are tolerated if 0.1 < CR < 0.2 and rejected if CR > 0.2. CR is given by the following equation:

$$CR = CI/RI \quad (2)$$

where RI is the Random Index: a constant which depends on the order of the matrix (see Saaty, 1987; p. 171) [67], and CI is the Consistency Index calculated by the equation:

$$CI = (\lambda max - n)/(n - 1) \quad (3)$$

where n is the number of items compared in the matrix and λmax is the maximum value of the eigenvalue that is obtained by the equation:

$$\lambda max = (1/n) \sum_{i=1}^{n} (WV_i/W_i) \quad (4)$$

where $\sum_{i=1}^{n} (WV_i/W_i)$ = vector coherence (C), W_i = the weighting coefficient estimated according to Table 2 and WV_i = weighted sum vector (calculated according to Table 3).

Table 3. Calculation of the weighted sum vector (WV_n) (where W_i = weighting coefficient (Table 2) and a_{ij} = preference values (Table 1)).

$$WV_1 = a_{11}W_1 + a_{12}W_2 + \ldots + a_{1n}W_n$$
$$WV_2 = a_{21}W_1 + a_{22}W_2 + \ldots + a_{2n}W_n$$
$$\ldots$$
$$WV_n = a_{n1}W_1 + a_{n2}W_2 + \ldots + a_{nn}W_n$$

3.3. Weighted Linear Combination (WLC)

The total score of the basic flood-hazard assessment for the study area was calculated with the linear combination of the selected factors/parameters, taking into account the relative weights. This involves superimposing the thematic maps with different weights in a vector-based GIS environment. The inclusion of the estimated factors was performed using the Weighted Linear Combination method, according to the following mathematical formula:

$$H = \sum_{i=1}^{n} W_i X_i \quad (5)$$

where H is hazard degree, n is the number of factors, W_i is the weight of factor i and X_i is the rating of factor i, as shown in Table 4.

Table 4. Matrix assigned rate classes for individual factors.

Factor	Class	Rating
Slope (°)	≤2	4
	[2–6]	3
	(6–12]	2
	(12–20]	1
	>20	0
Distance from stream channels (m)	Third order stream	
	[0–10]	4
	(10–20]	3
	(20–30]	2
	(30–40]	1
	>40	0
	Fourth order stream	
	(0–15]	4
	(15–30]	3
	(30–45]	2
	(45–50]	1
	>50	0
	Fifth order stream	
	[0–20]	4
	(20–40]	3
	(40–60]	2
	(60–80]	1
	>80	0
	Sixth order streaam	
	(0–25]	4
	(25–50]	3
	(50–70]	2
	(70–100]	1
	>100	0
Land cover	Dense urban area	4
	Sparse urban area	3
	Agricultural area	2
	Sparse vegetation	1
	Forest	0
Elevation (m a.m.s.l.)	≤50	4
	(50–100]	3
	(100–200]	2
	(200–500]	1
	>500	0
Geological formations	Impermeable	3
	Semi-permeable	2
	Permeable	1

The flood-hazard level scores of the study area were then classified into five classes using the quantile classification method, and the final basic flood-hazard map was created. Class 1 of the lower values corresponds to areas of very low flood susceptibility, class 2 corresponds to parts of the catchment with low flood susceptibility, class 3 to moderate susceptibility, class 4 to high susceptibility and, finally, class 5 of the highest values corresponds to extremely flood-prone areas.

The influence of the uncertainty of the adopted factor weights on the flood-hazard assessment was estimated using the following formula [8,68]:

$$\Delta S = \sqrt{\sum_{i=1}^{n} (\Delta W_i X_i)^2} \quad (6)$$

where ΔS is the error produced by independent errors ΔW_i in the weighting coefficient values and X_i is the rating of factor i.

Equation (6) was applied to calculate the error (ΔS). The independent errors (ΔW_i) were set as 20% of each original factor weight for all the factors at the same time [8,69]. After, it was multiplied by 1.96 in order to compute 95% confidence level in the suitability values S. The map created by this process was used to calculate the upper and lower S values at 95% confidence level, once by adding it and once by subtracting it from the basic flood-hazard map. The two resulting maps represent the scenarios of maximum and minimum S values for the catchment.

3.4. Verification of the Flood-Hazard Assessment

For verification of the flood-hazard assessment, the spatial distribution of the past 45 severe flood events that occurred in the Megalo Rema River catchment was used, as shown in Figures 7a,b and 8. The geographic distribution of the 45 flood events was produced by plotting, as a map layer, the points referring to the sites affected by severe flood incidences. These flood events, which occurred during the last 30 years, were retrieved from the archives of the Region of Attica, the Hellenic Fire Service, the Hellenic Agricultural Insurance Organization and the Ministry of Environment and Energy. The verification was performed by applying a frequency ratio statistical analysis. For this purpose, firstly, the frequency distribution of flood events was calculated for each hazard level zone of the basic flood-hazard map (see Table 9). Then, the ratio of each flood-hazard level zone area (from very low to very high) to the total area of the catchment was computed. The frequency ratio for each flood-hazard level zone was calculated by dividing the percentage of the events (out of the total 45 events) which appear in each hazard level zone by the area percentage of each hazard level zone area, which is presented in Table 7.

The accuracy of the basic flood-hazard map was also examined, taking into consideration the results of the delineation of the potentially flooded area on both sides of the main channel of the river performed by Andreou et al. [47], by simulating the river hydraulics behavior using HEC–RAS Model in GIS Environment for the main stream channel for about 4 km before the river mouth. Detection of the potentially flooded areas was performed for three different high discharge values that correspond to the peak discharges of the storm events on 22 February 2013, as well as to the discharge values over return periods of 25 and 50 years, respectively. Furthermore, the results of the quantitative geomorphological analysis regarding irregularities in the hierarchical drainage by stream order performed for the Megalo Rema (Rafina) drainage network by Karymbalis et al. [42] were considered.

Finally, to obtain a preliminary assessment of the impacts of the flash flood events on the socio-economic activities of the study area, land use of the catchment was identified utilizing the Urban Atlas 2018 data of Copernicus Land Monitoring Service (see Table 8). Initially, twenty-one land use types were recognized and further grouped into eight categories according to the density of the urban fabric, the sector of economy and the vegetation density. The percentage of each one of these socio-economically and environmentally important land use classes that occupy each flood-hazard level zone of the final map was estimated by overlaying the layer of land use to the basic flood-hazard map.

4. Results and Discussion

4.1. Factor Classification

Thematic maps in Figures 3, 4 and 5a illustrate the spatial distribution of the parameters' values of slope, distance from stream channels and land cover in the catchment after their classification into five groups according to their impact on flooding.

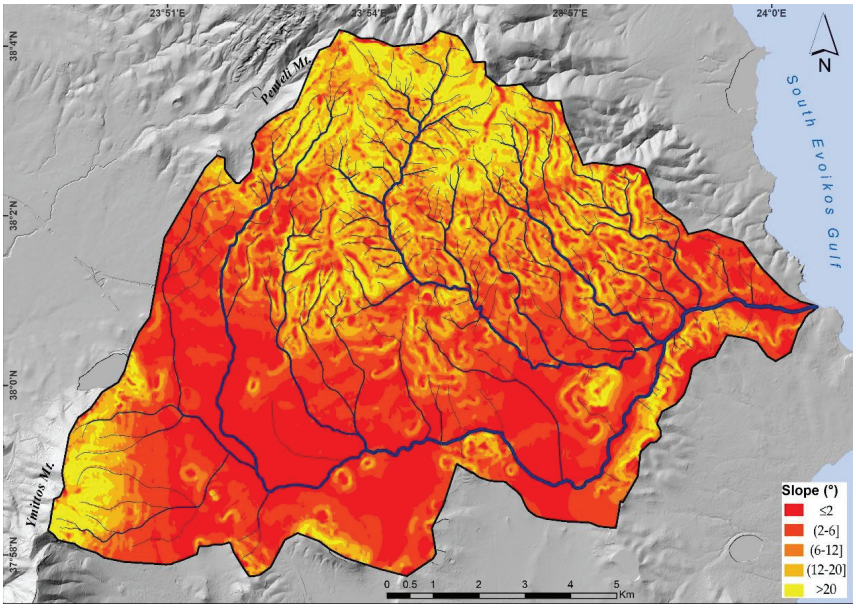

Figure 3. Thematic map showing the five classes of slopes. According to the rating adopted in the methodology, the five classes of slope were assigned the rating values as shown in Table 4.

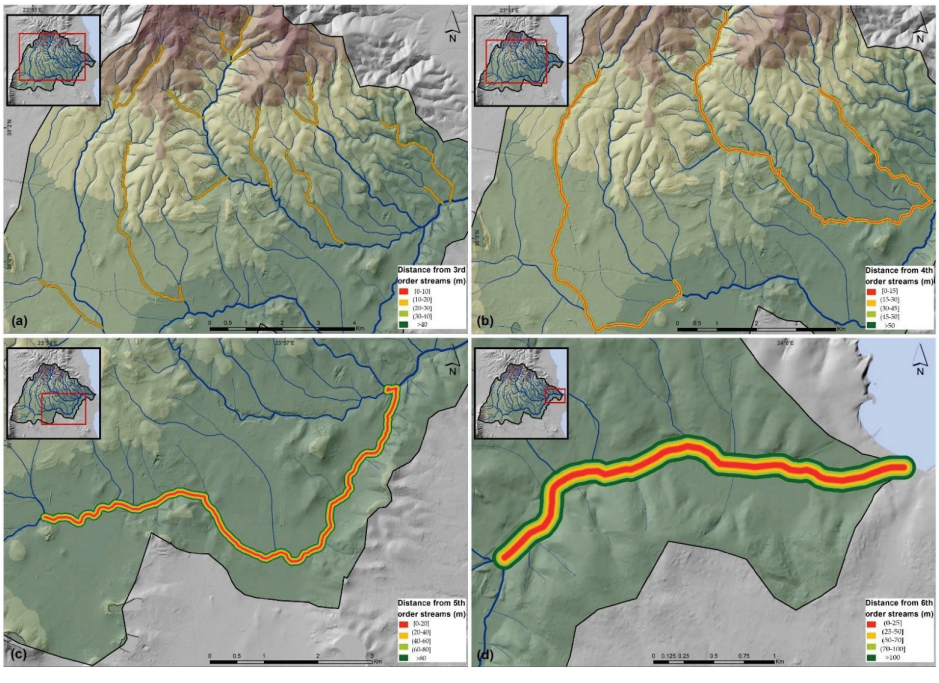

Figure 4. Thematic maps showing the distance from the stream channels for the third order streams (**a**), the fourth order streams (**b**), the fifth order streams (**c**), and the sixth order stream (**d**). The classes were assigned to the five-grade rating scale according to Table 4.

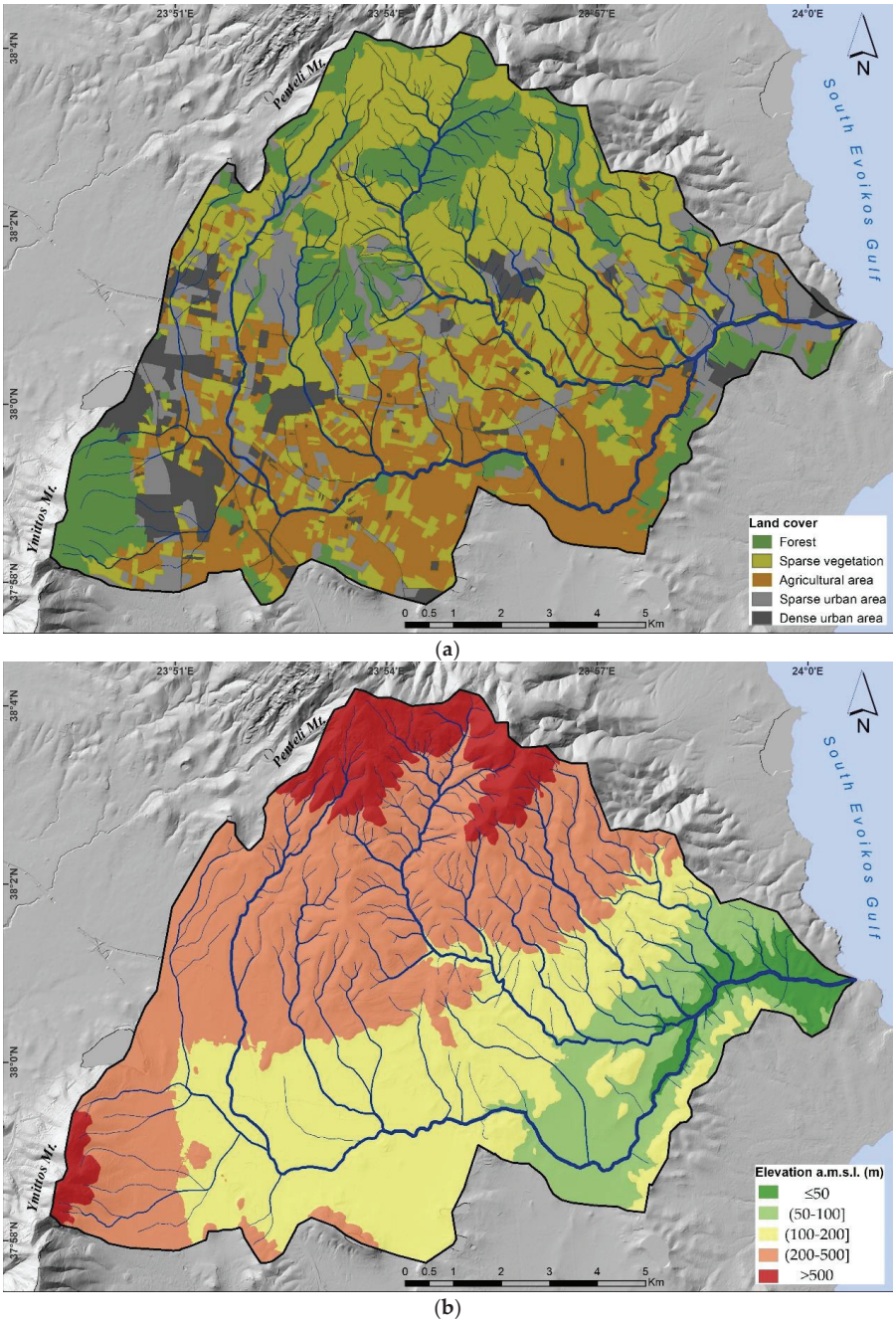

Figure 5. Thematic maps showing the five classes of the land cover type (**a**) and the elevation (**b**) that were assigned to the five-grade scale according to Table 4.

Regarding "slope", the range of the slope values lie between 0 and 44°. The thematic map of this criterion shows that a significant part of the study area (approximately 54%

of the total catchment area) belongs to the highly and very highly susceptible to flooding gently sloping zone, since it is characterized by low (≤2°) and very low (2°–6°) slope values (Figure 3). On the contrary, about 10% of the catchment area has slope values >20° and is characterized as having very low susceptibility to flooding. The classes were assigned these rating values as depicted in Table 4. The highest slopes are found at the northern, and southwestern parts of the study area where the mountainous landscapes of Penteli and Ymittos Mountain exist, as well as at the hilly area along the southeastern water divide.

According to the ranking followed for the criterion "distance from the stream channels", riparian areas in immediate proximity to the channel bed of the higher Strahler's steam order of the drainage network are highly and very highly susceptible to flooding. These areas are located along the main channels of Megalo Rema and its major tributaries Valanaris and Krioneri (Figure 4).

Dense and sparse urban areas, which are highly and very highly susceptible to flooding, primarily dominate the western and eastern parts of the catchment, while the southern part of the study area along the main stream channel mainly hosts agricultural activities (Figure 5a). The mountainous parts of the catchment are less susceptible to floods, in terms of the land cover parameter, since they are covered by forests and sparse natural vegetation.

The elevation of the catchment ranges from 0 to 950 m. High-elevation (between 200 m and 500 m, as well as higher than 500 m) appears in the northern and western mountainous parts of the catchment. On the contrary, the lower elevation zones more susceptible to flooding (≤50 m and 50–100 m) are located on both sides of the main stream channel at the eastern and southern portions of the catchment (Figure 5b).

The classification of the geological formations of the catchment into three groups according to their hydrogeological behavior showed that the prevailing geological formations belong to the semi-permeable group (Figure 6). The northern part of the catchment is dominated by impermeable rocks, whereas the westernmost part, as well as the broader area of the river mouth, is covered by permeable geological formations.

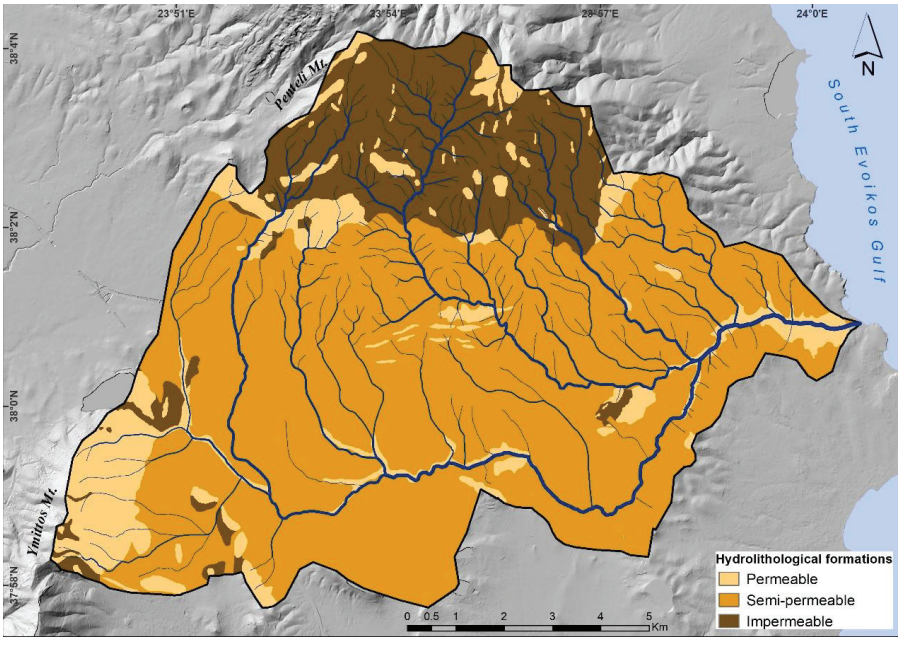

Figure 6. Thematic maps showing the classes of the hydrological formations that were assigned to the three-grade scale according to Table 4.

4.2. Multi-Criteria Decision Analysis (MCDA)—Flood-Hazard Assessment

The thematic maps of the spatial distribution of the five factors (Figures 3–6) were used as inputs in the MCDA. All values of all the parameters involved are classified into five classes and assigned to a uniform suitability five-grade rating scale. Higher classified ranking values correspond to areas more susceptible to floods, while lower values correspond to less flood-prone areas. Table 4 includes the factors/parameters, their classes and their ratings. All the parameters are assigned with ratings from 0 to 4, whereas the geological formation classes are assigned with ratings of 1 to 3, since there are no ideally permeable or impermeable geological formations. For this reason, the ratings 0 and 4 were not selected.

The results of the AHP procedure, the extraction of criteria weights and the calculation of the CR are shown in Table 5.

Table 5. Values of the pairwise comparisons were obtained according to experts' judgments based on their experience in flood-hazard analysis. The values in the table represent the mode of the values suggested by the experts. The table continues with the calculation of weighting coefficients and calculation of CR. (F1: Slope, F2: Distance from stream channel, F3: Land cover, F4: Elevation, F5: Geological formations, W: weights, WV: vector of weighted sum, C: coherence vector, λ: maximum value of eigenvalue, CI: consistency index, CR: consistency ratio).

Pairwise Comparisons									
	F1	F2	F3	F4	F5				
F1	1	1	3	4	9				
F2	1	1	3	4	9				
F3	0.33	0.33	1	3	5				
F4	0.25	0.25	0.33	1	3				
F5	0.11	0.11	0.20	0.33	1				
Sum	2.69	2.69	7.53	12.33	27.00				
Calculation of Weighting Coefficients and Calculation of CR									
	F1	F2	F3	F4	F5				Sum
F1	0.37	0.37	0.39	0.32	0.33				1.80
F2	0.37	0.37	0.39	0.32	0.33				1.80
F3	0.12	0.12	0.13	0.24	0.18				0.80
F4	0.09	0.09	0.04	0.08	0.11				0.42
F5	0.04	0.04	0.02	0.02	0.03				0.17
Sum	1.00	1.00	1.00	1.00	1.00				
CR Calculation									
	W		W	WV	C	λmax	CI	RI	CR
F1	0.360	F1	0.360	1.851	5.143	5.086	0.021	1.12	0.019
F2	0.360	F2	0.360	1.851	5.143				
F3	0.161	F3	0.161	0.824	5.109				
F4	0.084	F4	0.084	0.421	4.988				
F5	0.033	F5	0.033	0.174	5.046				
Sum	1.00				25.429				

The calculated CR (Table 5) in this study is 0.019 (lower than the threshold 0.1) within the range for the acceptance of the consistency of judgments in the pairwise comparison matrix. Consequently, the weights' consistency is affirmed.

As described in the methodology, the flood-hazard level values were calculated following the WLC procedure, using the classified and normalized values of the five criteria involved and their weighting coefficients (Tables 4 and 5). The final basic flood-hazard assessment map (Hbasic) is presented in Figure 7a. It was produced after the reclassification of the flood-hazard level values into five categories (from very low to very high) with the quantile classification method. In addition, two other maps characterizing the maximum (Hmax = Hbasic + ΔS) and minimum (Hmin = Hbasic + ΔS) flood-hazard level values were produced (Figures 7b and 8) after the examination of the influence

of uncertainty of the adopted factor weights on the flood-hazard assessment. This was necessary since uncertainty plays an important role in natural hazard evaluation [70,71] and can bias the outcome of every hazard assessment. The uncertainties of the weighting coefficient for each factor (ΔW_i) are shown in Table 6.

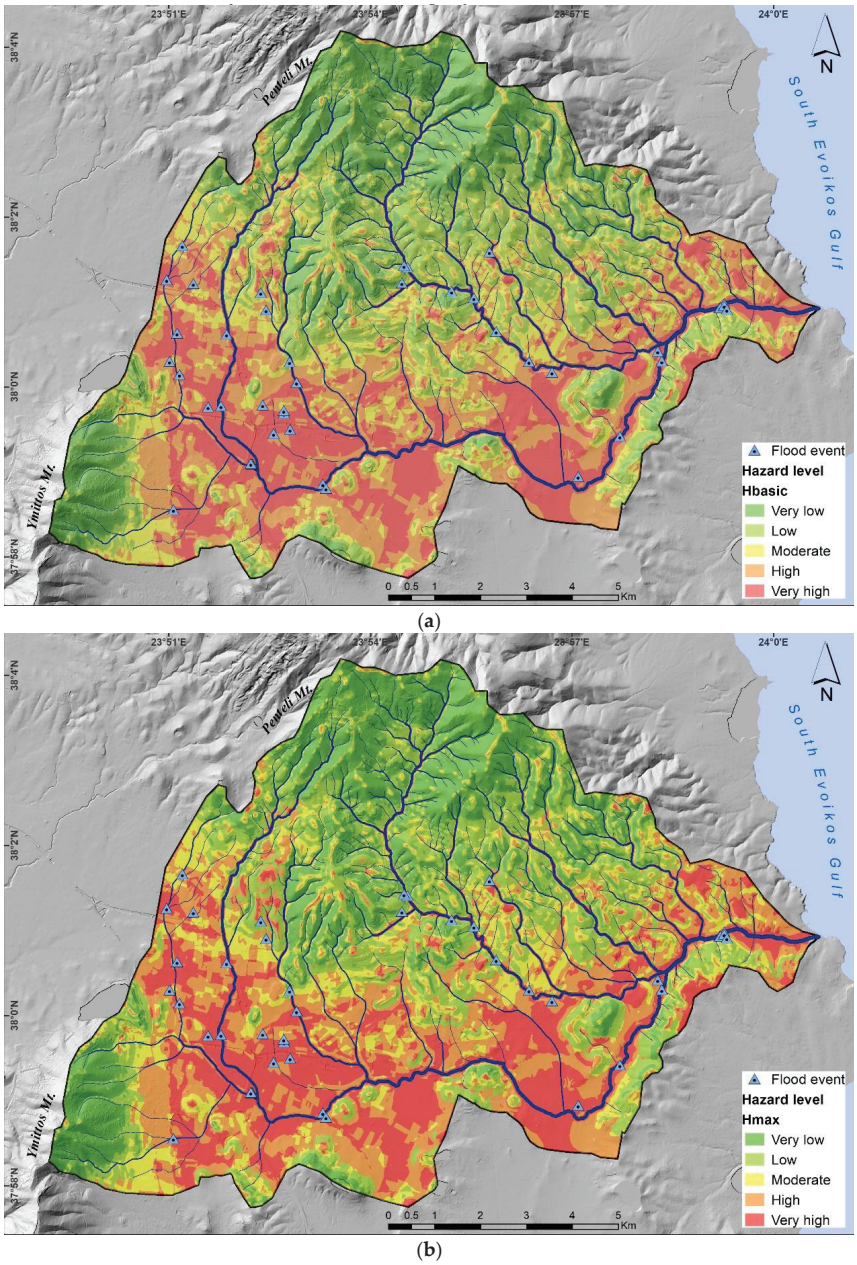

Figure 7. Maps illustrating (**a**) the basic flood-hazard (Hbasic) assessment map and (**b**) the higher (Hmax) values of the flood-hazard assessment.

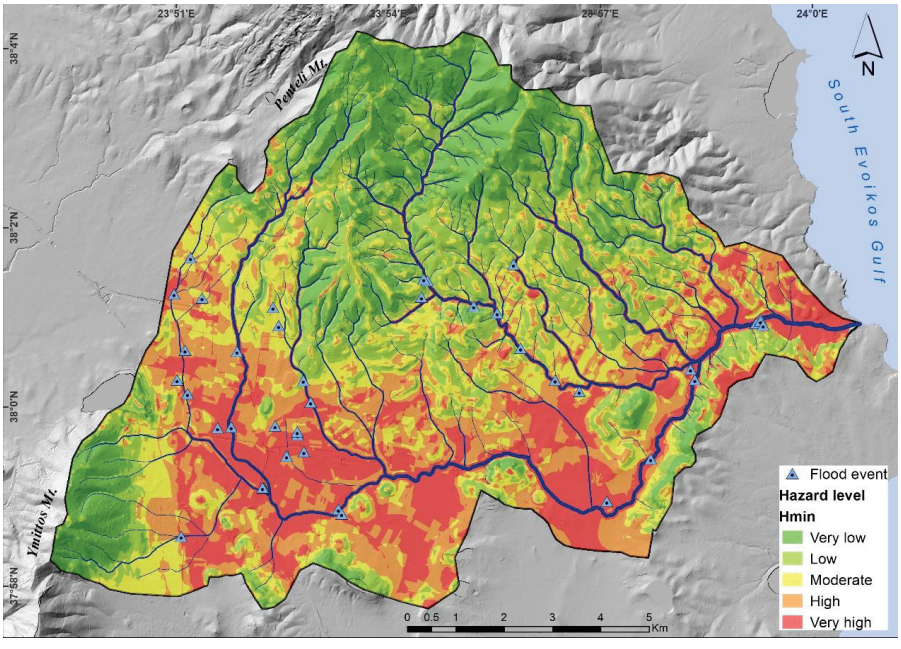

Figure 8. The lower (Hmin) values of the flood-hazard assessment.

Table 6. The uncertainties (ΔW_i) of the weighting coefficient for each factor.

Factor	ΔW_i
Slope	0.0720
Distance from stream channel	0.0720
Land cover	0.0322
Elevation	0.0168
Geological formations	0.0066

Regarding the spatial development of the five flood-hazard zones, the percentages corresponding to the area of each hazard zone for the three flood-hazard assessment maps (Hbasic, Hmax and Hmin) of Figures 7 and 8 are included in Table 7. An area of 26.3 km^2, which corresponds to the 22.7% of the total catchment, belongs to the high flood-hazard zone, while 24.7 km^2 (some 21.3% of the catchment) is very highly prone to flooding. The areas of the high flood-hazard zones of the maximum flood-hazard assessment value map (Hmax) are negligibly increased compared to the corresponding zones of the basic map (Hbasic), whereas the areas of the very high flood zone are negligibly lower. This similar comparison proves that the spatial extents of moderate hazard zones decrease, while the moderate, low and very low hazard zone increase. Comparing the zones of the map of the minimum value of the flood-hazard assessment (Hmin) to those of the basic map (Hbasic), the areas of high and very high flood-hazard zones decrease, whereas the moderate, low and very low hazard areas slightly increase.

The resultant flood-hazard assessment maps indicate that the areas of very high and high flood-hazard are distributed mostly on the lower reaches of the Megalo Rema River, along the main stream channel and around the mouth of the River (Figures 7a,b and 8). Additionally, an extensive low-lying area at the southern and western parts of the catchment belongs to the zones of high and very high flood-hazard risk. The flood-hazard map shows that the urban areas on both sides of the main channels of the drainage network are more prone to flooding. It is evident that these parts of the catchment are

relatively low-lying, of gentle slope and densely populated. They include residential areas of the Rafina-Pikermi, Penteli, Pallini, Peania, Spata, Glika Nera, Gerakas and Anthousa settlements, with a total population of ~85,000 residents. This high population density is directly associated with the urbanization of this area, which increases the surface runoff during extreme rainfall events and contributes to an increased human exposure and social vulnerability to the flood-hazard. The northern and the southwestern mountainous parts of the study area are low and very low flood-hazard areas. Limited regions at the central part of the catchment are classified as being of high and very high flood risk; those that are include the settlements of Dion, Kallitechnoupolis and Drafi.

Table 7. Area (in km^2 and percentage) of the catchment in each flood-hazard zone (areas are shown in Figures 7 and 8).

	Hbasic		Hmax		Hmin	
Hazard Ranking	**Area km^2**	**Area %**	**Area km^2**	**Area %**	**Area km^2**	**Area %**
Very Low	20.39	17.56	23.11	19.91	20.78	17.90
Low	24.47	21.08	25.38	21.87	25.64	22.09
Moderate	20.15	17.36	16.55	14.25	21.87	18.84
High	26.35	22.70	26.67	22.98	24.01	20.68
Very High	24.72	21.30	24.37	20.99	23.79	20.49
Total	116.08	100.00	116.08	100.00	116.08	100.00

The distribution of land use in the susceptible to flooding zones of the Hbasic flood hazard map is illustrated in the bar charts of Figure 9. Accordingly, 30.6% and 37.0% of the high and very high flood-hazard zones are occupied by agricultural land and related activities. Significant parts of the highly prone to flooding areas correspond to continuous and discontinuous dense urban fabric (12.6%), discontinuous medium- and low-density urban fabric (15.1%) and industrial, commercial, public and private units and construction sites (7.2%). Similarly, dense urban fabric, medium- to low-density urban fabric and industrial, commercial, public and private units and construction sites constitute 9.4%, 13.5% and 10.1% of the very high flood risk zone, respectively. It is worth noting that some 9.9% and 9.5% of the high and very high flood-prone areas, respectively, consist of road network and associated land. Very low to moderate prone areas appear mainly at forests and areas covered by natural vegetation (see Table 8).

Table 8. Area of each land use type in Megalo Rema catchment, according to Urban Atlas 2018 data of Copernicus Land Monitoring Service.

Urban Atlas 2018 Land Use	**km^2**
Forests, herbaceous vegetation associations (natural grassland, moors, etc.)	51.10
Arable land (annual crops), permanent crops (vineyards, fruit trees, olive groves), pastures, complex and mixed cultivation patterns	24.08
Fast transit roads and associated land, other roads and associated land	8.36
Open spaces with little or no vegetation (beaches, dunes, bare rocks), sports and leisure facilities, land without use	0.86
Industrial, commercial, public, military and private units, mineral extraction and dump sites, construction sites	5.90
Discontinuous very low density urban fabric (S.L.: <10%), isolated structures, green urban areas	2.52
Discontinuous medium- and low-density urban fabric (S.L.: 10—50%)	13.57
Continuous and discontinuous dense urban fabric (S.L.: >50%)	9.69

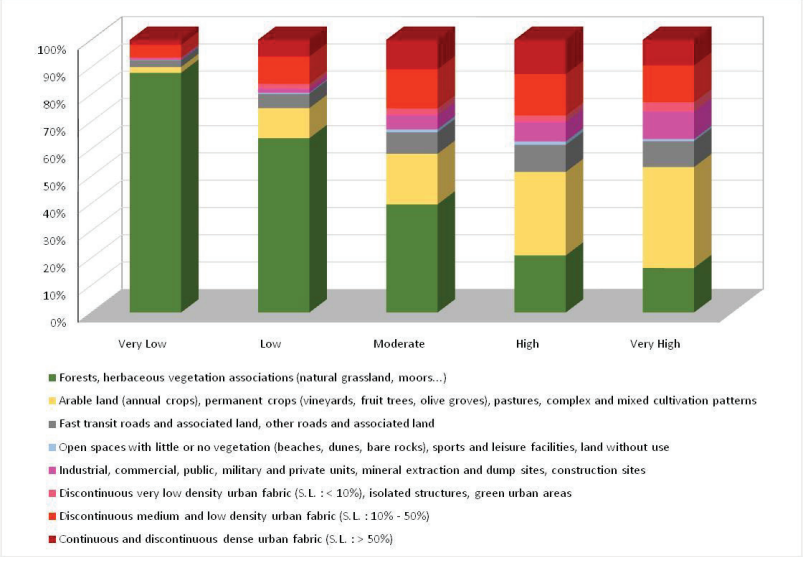

Figure 9. Distribution of land use according to flood-hazard level.

The analysis performed by Giannaros et al. [48] in an attempt to introduce an operational impact-based warning system in the area, coupling a state-of-the-art numerical weather prediction model with an advanced, spatially explicit hydrological model, provided some preliminary discharge thresholds in terms of flash flooding's socioeconomic impacts. Minimal impact was reported when the peak discharge in the mouth of Megalo Rema was lower than 20 m^3/s, whereas maximum stream discharges that ranged from 20 m^3/s to 40 m^3/s were associated with major impact. Significant impact was induced by events that were characterized by peak stream flows higher than 40–60 m^3/s. These thresholds are considered as preliminary since their reliability is mainly moderated due to the lack of discharge data along the entire length of the Megalo Rema stream [48].

The flood-hazard assessment map provides valuable information for land-use planning at a regional scale, leading to the determination of safe and unsafe areas for urban development [72,73]. Even though hazard maps represent a snapshot situation regarding flood-hazard level variation within the catchment, they could still support policy makers with knowledge for future planning. This is very important, particularly for the study area, since the land cover properties are constantly changing. This can be attributed primarily to two factors: forest fires that devastated a significant part of the forested land of the area and the increased urbanization rate of the area, especially during the last 40 years. The increase in the population of the Municipality of Rafina-Pikermi and Penteli for the period between 1981 and 2011 was estimated up to 70% and 60%, respectively (Source: Hellenic Statistical Authority). One of the main reasons for this positive population growth is the construction of several public works in this area (i.e., the new international airport of Athens in Spata, the Attiki Odos motorway and the developing Rafina port), which contribute to a significant increase in private building activity in the neighboring settlements and Municipalities [74].

4.3. Verification of the Flood-Hazard Map's Accuracy

The accuracy of the basic flood-hazard map was verified by means of the frequency ratio and flood events which affected the study area over the past 30 years. The findings established that the vast majority of the flood events, almost 89% (40 out of 45 incidents), occurred within the limits of the high and very high flood-hazard zones (Table 9). The frequency ratio is higher than one in the high and very high flood-hazard zones, which

is indicative of the strong positive correlation between the hazard zones and the flood occurrences, since the flood-hazard intensity raises as the frequency ratio values increase (Table 9).

Table 9. Frequency ratio values of flood events in the flood-hazard zones of the basic map (Hbasic).

Hazard Ranking	Area %	Number of Flood Events	Cum Freq	Flood Events %	Frequency Ratio
Very Low	17.56	0	0	0.00	0.00
Low	21.08	2	2	4.44	0.21
Moderate	17.36	3	5	6.67	0.38
High	22.70	15	20	33.33	1.47
Very High	21.30	25	45	55.56	2.61
Total	100.00	45		100.00	

Another way of validating the results of the final flood-hazard map is by overlaying the outcome results of the application of the one-dimensional steady flow hydraulic model HEC–RAS and comparing the potentially flooded areas with the borders of the high and very high flood-hazard zone. The flood-hazard mapping is in accordance with the results of the delineation of the potentially flooded area on both sides of the main stream channel, by simulating the river hydraulics' behavior using the HEC–RAS Model in a GIS environment for the last 4 km of its course before the river mouth (Figure 10) [47]. The detection of potentially flooded areas was performed for three different high discharge values that correspond to the peak discharges of the storm events on 22 February 2013, as well as to the discharge values over return periods of 25 and 50 years, respectively. According to the results of the hydraulic model, the potentially flooded areas coincide with the highly and very highly flood-hazard prone areas, as mapped in this study. The results of a HEC–RAS simulation, taking into account higher discharges (i.e., a 100-year return period), would show that more of the high and very high flood-hazard zone could be included in the flood's extent, possibly including the flood event that lies in the moderate flood-hazard zone and outside the flooding extent of the simulation results in Figure 10.

The resultant flood-hazard map is also in line with the quantitative geomorphological analysis performed for the Megalo Rema drainage network by Karymbalis et al. [42]. The results of the aforementioned geomorphological analysis show irregularities in the hierarchical drainage by stream order that enhance flash floods. The most significant among them concerns the fourth order streams that drain directly into the sixth order main stream channel of the Megalo Rema (Rafina). The reason for this is the Neos Voutzas stream which joins the main channel at its lower reaches, enhancing its discharge when high precipitation events occur at the upper reaches of this tributary. This assumption is supported by the flood-hazard map of the present study, in which the broader area of the confluence of these two streams belongs to the very highly prone to flooding zone.

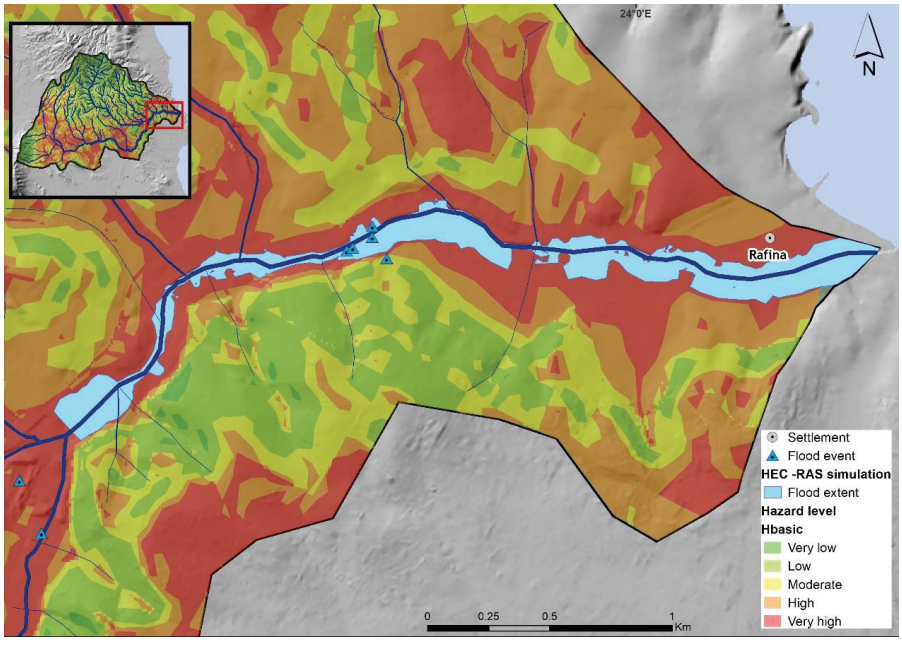

Figure 10. Map depicting flood extent according to the HEC–RAS simulation of the 50-year return period in relation to the Hbasic map for the last 4 km of the river course (based on Andreou et al. [47]).

5. Conclusions

The aim of the present paper was the development of a catchment scale methodology to identify and map the zones prone to flooding in the fast-growing urban catchment of Megalo Rema in East Attica, Greece. The proposed methodology was based on MCDA integrated with GIS (GIS-based MCDA) using AHP and took into account various critical factors such as slope, distance from stream channels, land cover, elevation and geology.

The flood-hazard assessment map produced showed that 51 km^2, which corresponds to 44% of the total catchment area, belong to the high and very high flood-hazard classes. The areas most prone to flooding are the low-lying, gently sloping and densely urbanized southern and western parts of the catchment, as well as the area of the river mouth. The areas highly prone to flooding host socioeconomically significant land uses such as continuous and discontinuous dense urban fabric (12.6%), discontinuous medium- and low-density urban fabric (15.1%) and industrial, commercial, public and private units and construction sites (7.2%). Similarly, the zone of very high flood risk is occupied by dense urban fabric (9.4%), medium- to low-density urban fabric (13.5%) and industrial, commercial, public and private units and construction sites (10.1%). In addition, 9.9% and 9.5% of the high and very high flood-prone zones of the catchment consist of the road network and its associated land, while 30.6% and 37.0% of these zones are occupied by agricultural land and related activities.

A significant correlation between the flood-hazard zones and the spatial distribution of past flood phenomena was detected, calculating the frequency ratio of the flood events as shown in Table 9. The flood-hazard map is also in accordance with the results of the quantitative geomorphological analysis of the Megalo Rema drainage network, as well as with the potentially flooded areas delineated by simulating the hydraulic behavior of the lower reaches of the river using the HEC–RAS Model. These verifications demonstrated the reliable results and high accuracy achieved by the created flood-hazard map.

The proposed methodology is simple and provides a tool for the improvement of flood risk management strategies and action plans, while it can also be useful in land use planning projects at a catchment scale.

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Disaster Risk Awareness: The Turkish Migrants Living in Northern Italy

Funda Atun [1,*] and Chiara Fonio [2]

[1] Department of Urban and Regional Planning and Geo-Information Management, Faculty of Geo-Information Science and Earth Observation, University of Twente, 7514 AE Enschede, The Netherlands
[2] Faculty of Social Sciences, Organization Sciences, Vrije Universiteit Amsterdam, 1081 HV Amsterdam, The Netherlands; c.fonio@vu.nl
* Correspondence: f.atungirgin@utwente.nl

Abstract: In this study, we analysed the socio-demographic characteristics and disaster risk awareness of the Turkish migrants living in northern Italy. We initiated the study with an extensive face-to-face questionnaire with 544 individual respondents. With the help of the questionnaire, we gathered information on the socio-demographic structure of the Turkish community living in the area and the immigrants' disaster experience, their level of disaster preparedness and disaster risk awareness, and their potential behaviour during an emergency. Additionally, we conducted focus group meetings in Milan, Lecco, Como and Varese with 49 migrants living in the region. In the focus group meetings, we discussed the migrants' awareness of disasters and potential behaviour patterns during emergencies. We collected the informative booklets and past event reports prepared by civil protection centres and municipalities and used them in focus group meetings to collect participants' opinions. The results show that the migrant communities' disaster risk awareness is low, but their capacity to adapt to suddenly changing conditions is higher than presumed.

Keywords: disaster risk awareness; migrants; disaster preparedness; earthquake; flood; Italy; Turkey

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1. Introduction

Scholars have long studied the variety of reasons that people migrate from one place to another. Human mobility has a long history and understanding migration patterns has been central to migration studies for decades. The most significant drivers are often structural (e.g., economic development in the countries of origin) [1]. However, there is no simple explanation such as the pull and push factor, and the migration decision depends on complex interactions of many factors [2]. UNHCR [3] states that migrants and receiver countries benefit from migration, and it enriches their current situations. UNHCR [3] also indicates the situations that leave migrants in vulnerable conditions, and "situational vulnerability" is one of them. Migrants' situational vulnerability is higher than that of the inhabitants for many reasons, the primary one being a lack of knowledge of the local risks and language.

Despite the importance of the issue, many studies on migration and disaster risk management are very limited; they mainly focus on non-European countries and revolve around the specific impact of the hazard, e.g., the effect of storms on migrant communities [4,5]. There are a wide range of studies on post-disaster migration [6]. However, there are few on migrants' perception and awareness of risk and preparedness level [7]. The concepts of risk perception and preparedness have often been associated in many disaster studies not necessarily focused on migrants and framed along the lines of "prediction". Namely, risk perception is a predictor of preparedness behaviour [8].

Migrants are considered the "(in)visible victims of disasters" whose unique needs are often overlooked in disaster planning [9]. Unequal access to disaster preparedness resources is coupled with a poor understanding of migrants' risk perceptions, which

vary by ethnicity and culture. Not only is unequal access to resources an important variable, but also underrepresentation in local government and voluntary organisations such fire brigades or The Red Cross turns migrants into invisible actors in decision-making processes [10].

Concerns about their legal status are worth noting here for several reasons; inter alia it can influence both risk perceptions and behaviours during emergencies [11]. Studies show that legal status is an important determinant in disaster zones [12].

Tackling and understanding migrants' perception and awareness of risk entails adopting a comprehensive and multi-faceted approach that considers a wide variety of socio-cultural and economic factors. Such an approach is also a pre-condition for ensuring proper inclusion in disaster risk reduction (DRR) policies and activities which, in turn, would be consistent with the approach adopted by the Sendai Framework for Disaster Risk Reduction 2015–2030 [13].

> While practices (projects, activities, training and platforms) for the inclusion of migrants in DRR have significantly increased in the past few decades, "*a variety of efforts are needed [. . .] ranging from identification of migrants' specific conditions of exposure and vulnerability, through the design of migrant-inclusive preparedness plans, and early warning and emergency communications systems, to the active engagement of migrants in disaster management structures*". [13] (p. 14)

Around twenty-five years ago, Susan Cutter asked 'are societies more vulnerable to environmental hazards?' and pioneered the first comprehensive social vulnerability index, which generally includes qualitative indicators rather than quantitative [14]. Social vulnerability is mostly described by individual characteristics of people, such as age, race, health, income, type of dwelling unit and employment [15] (p. 243). The other factors that increase the social vulnerability of a community are a lack of access to resources such as information, knowledge and technology, limited access to political power, absence of social capital, beliefs and customs, deficiency of physical environment, individuals with disabilities, and type and density of infrastructure [16–19] (cited in [20], p. 245).

Findings from qualitative research, in fact, show that people may be simultaneously vulnerable and resilient [20]. This knowledge led to an important conceptual shift, as it challenges ideas of migrants as passive victims to emphasise their potential role as resourceful agents [20] (p. 6). Studies have also highlighted the key role of social capital in resilience, especially in environments with cultural and language barriers [21].

Additionally, with regard to preparedness, it is a well-known fact that people living in hazard-prone areas are often unprepared, and they fail to take precautionary measures to reduce the impact of a disaster [22,23] (cited in [24]). Communication is one of the many reasons for this. How risk communication is conceived by actors involved in disaster risk management can make a difference [25]. As highlighted by the Intergovernmental Panel on Climate Change [26], taking into account the specific needs of different societal groups is key. Communication processes should be as inclusive as possible, meaning that local risk perceptions and the local framing of risks and needs cannot be ignored since, for instance, language skills influence the levels of disaster preparedness [27]. As Fielding pointed out, different people and different locations require additional warnings [26]. Targeting group-specific information based on the heterogeneity of citizens is crucial [28].

Other relevant terms are place attachment [29], sense of community [30] and sense of place [30]. The study by Misshra et al. [29] asked the question "*Does place attachment and the consequent emotional connections and ties that people have with environments affect their preparedness for natural disasters, such as floods?*" The authors addressed the research question by considering the three attachment types: "*economic, genealogical, and religious*". The results show that there is a strong correlation between place attachment and flood preparedness. Place attachment can be considered one of the differences between migrants and local inhabitants. Regarding the sense of community, it requires further studies to investigate the impact of "sense of community" [30] and "sense of place" [31] on the preparedness and awareness of migrants.

We started this study with the problem being that the migrants are invisible victims whose unique needs are not included in disaster planning. Another challenge is that they are often labelled as vulnerable, and their capacities are overlooked in disaster risk studies. In this study, we collect information on the socio-demographic characteristics of migrants and their access to resources such as information, knowledge and technology that helps us to understand the social vulnerability of migrants. The results of the study will help decision makers to adjust disaster risk planning by considering the unique needs of the migrants based on their socio-cultural and economic conditions. It is worth considering that it would be misleading to frame the risk awareness and preparedness of migrants only through the concept of "vulnerability" without considering their capacities as well.

2. Materials and Methods

In the study, we applied various research methods at three different urban scales: regional, community, and household. The study started with a face-to-face questionnaire conducted during the National Parliamentary Elections in May 2015 in Milan. We administered the questionnaire to 544 individuals. The respondents were selected randomly at the entrance of the Consulate General of the Republic of Turkey in Milan by researchers. The questionnaire gathered information on the Turkish community's socio-demographic characteristics, their disaster experience, disaster preparedness, disaster awareness, and their potential behaviour during an emergency. To collect further information and gather in-depth knowledge on the awareness of disaster, we decided to conduct focus group meetings with various socio-cultural groups, including students, expats, religious minorities, and the members of a religious-political movement. Additionally, we conducted literature research regarding past natural hazards in northern Italy to inquire about visual and written resources during focus group meetings. The risk maps and reports that were prepared by the civil protection authorities and municipalities were examined on a regional scale. We collected the informative booklets and past event reports prepared by civil protection authorities and municipalities to analyse details and share them with participants during focus group meetings to learn more about the participants' experiences and opinions.

Due to the exploratory nature of this study, we started with some generalisations about the socio-demographic characteristics of the Turkish communities living in northern Italy. We presumed that most Turkish communities living in Italy are composed of workers in the food and construction sectors and students. The former has rapidly increased in recent years. The Italian education system became an option for students who do not speak Italian with the launch of English graduate programs. A small portion of the first incoming students decided to work or continue their doctoral or post-doctoral training. The rate, which was significantly small in the first few years, continues to increase every year.

2.1. The Survey Area

In Italy, the majority of the Turkish population lives in northern Italy; therefore, the study covers nine administrative regions in the service area of the Consulate General of the Republic of Turkey in Milan, located in the north of Italy. These regions are (1) Lombardia, (2) Valle d'Aosta, (3) Liguria, (4) Piemonte, (5) Veneto, (6) Trentino Alto Adige, (7) Emilia Romagna, (8) Marche, (9) Friuli Venezia Giulia (Figure 1). According to the information received from the Turkish General Consulate at the beginning of the project, in May 2015, approximately 29,000 citizens had been at the consulate for various consular procedures; however, it is not possible to obtain a concrete number of citizens residing in the functional area of the General Consulate. However, this number was estimated to be approximately 30,000 people by the employees of the Consulate General. The net number of Turkish citizens recorded in the voter roll through address declaration to the Consulate General of the Republic of Turkey in Milan was 10,373 (18 years old or older) as of May 2015, when we started the study. The regions that they were living in and the respective resident numbers of the 19,936 Republic of Turkey citizens who were reached through the database of the Consulate General are as follows: Lombardia, 11,236; Valle D'Aosta, 14; Liguria, 1777;

Piemonte, 1444; Veneto, 423; Trentino Alto Adige, 313; Emiligia Romagna, 4273; Marche, 70; Friuli Venezia Giulia, 386. These numbers reflect those who registered their address at the Consulate General and have legal rights to live in the region.

Figure 1. The green areas included in the survey.

2.2. Comprehensive Questionnaire: The Size of the Sample

There was no information on the socio-demographic status of the overall Turkish community. According to information obtained in May 2015, 10,373 residents out of 19,936 are registered voters in the Consulate General of the Republic of Turkey in Milan. Based on this number, the sample size was calculated as 544 individuals (Table 1). The number of families living in the region is unknown, so we used the number of registered voters to decide on the size of the sample.

Table 1. Calculation of the sample size.

Registered Voter Count	10,373 Registered Voters (May 2015)
Confidence level	95%
Percentage	50%
Confidence interval	4.09
Sample size	544 individuals

While preparing the questionnaire, the questions were designed to understand the socio-demographic characteristics of migrants, their disaster experience, their awareness of disaster risk and their preparedness level. The questions in the last section of the questionnaire were prepared to gather more information about the Turkish community's socio-demographic characteristics, such as the gender, age, educational status, and language skills of the sample who participated in the comprehensive questionnaire study. A set of questions were designed to understand the citizens' experience of disasters, disaster preparedness and mitigation actions. The third set of questions were designed to learn more about the participants' preferences for communication media and how often they use them. We wanted to select the most used communication tool to raise awareness about the risks of disasters in their regions of residence by sharing information leaflets and video messages.

The classification used in the survey is as follows:

- Disaster experience *
- Disaster preparedness *
- Potential behaviour of the respondents during disasters *
- Disaster awareness *
- Communication media tool *
- Socio-demographic characteristics

For the classifications with "*", the unit of analysis is individual. For "socio-demographic analysis", the unit of analysis is family. The last page of the questionnaire was composed of questions about the socio-demographic characteristics of the family members living in the same house, such as the number of people living in the house, their ages and education levels, and the languages that the family members speak at home to communicate. During the questionnaire, researchers were present at the site to help the individuals to fill in the questionnaires. In addition to questionnaire forms, we prepared visuals to support the respondents in understanding the questions. Five hundred and forty-four individuals filled out the questionnaires, and 525 families were represented in the study. When the individual disaster experience was different, we let more than one family member fill out the questionnaire. We stapled the questionnaires together when multiple family members filled out the questionnaire, and only one family member filled out the last page. When we calculated the number of family members, we found that we had the socio-demographic data of 1785 individuals.

2.3. Focus Group Meetings

We conducted focus group meetings in four different locations (Milan, Lecco, Como and Varese), considering the location and diversity of the Turkish migrants. In total, 49 migrants attended the focus group meetings (for details, please see Appendix A). We decided the contents and locations of the focus group meetings considering the results of the questionnaires. The purpose of the focus group meetings was not to compare the results with the questionnaire, but to gain in-depth knowledge on the awareness, needs, feelings, beliefs, behaviour patterns in a possible emergency, and priorities of various groups. At the beginning of each meeting, the primary investigator (PI) welcomed the participants, introduced herself and the project and the setting of the focus group meetings, mentioned the rights of the participants, and participants signed the consent forms that included information on the study and the participants' rights. Then, the participants were asked to introduce themselves. During focus group meetings, participants were asked ten questions. The meeting began by asking the participants to define "what is a disaster according to them". After these ten questions, participants were asked if they wanted to share anything else or whether they had questions for the researcher or not.

The focus group questions are as follows:

- What is a disaster? Please specify.
- Do you think that an environmental disaster, such as a flood or earthquake, will happen to you?
- During an emergency/disaster, what would be your priorities?
- During an emergency/disaster, what may you need?
- Who do you call first?
- During an emergency/disaster, how do you reach the information that you need?
- (Information resources covering the regions that they are living were shown to the participants in terms of visual materials.) Do you know these sources of information?
- How would you be aware of these resources?
- What can you do to protect yourself and your family from a disaster?
- If you experience a disaster/catastrophe, will you go back to Turkey?

During the focus group meetings, various hazard maps, disaster photos, and newspaper columns regarding the past events were shared with the participants. The severity and probability of the reoccurrence of these events were discussed to a large extent. In this way, we aimed to attract the participants' attention and carry out a more collaborative and interactive discussion. Furthermore, they had been encouraged to enhance their resilience in disaster risk management. Two MSc students assisted the PI during the focus group meetings. The focus group meetings were as follows; for more details, please consult Appendix A.

- Focus Group 1: MSc students in Lecco
- Focus Group 2: women residing in Milan

- Focus Group 3: men residing in Como
- Focus Group 4: families residing in Lecco
- Focus Group 5: researchers working at an international research organisation and their families residing in Varese.

2.4. Ethical Considerations and Data Management

Ethical aspects were at the centre of our study. We obtained the necessary permissions from the General Consulate of the Turkish Republic in Milan and the Turkish Republic Supreme Election Council to conduct the questionnaires during the parliamentary elections. We ensured honesty and transparency towards research subjects involved in several stages of the study, such as face-to-face questionnaires and focus group meetings. Participants voluntarily engaged in the study, and they were given the project's informed consent form and detailed information sheets in advance. The consent forms were in Turkish. We had two participants who required translation of the documents to Italian, and we translated all the documents for them to Italian. The consent form explicitly stated that participation is voluntary. Anyone has the right to refuse to participate and to withdraw their participation, samples or data at any time without any consequences. Participants gave their consent by signing a separate form from the questionnaire, as the questionnaires were anonymous. We did not collect more data than were necessary to reach the research goal. All data were handled in a manner that respected the rights specified in the agreements (informed consent and transfer of intellectual property).

3. Results

3.1. Results of the Questionnaire

The results of the questionnaire set out the socio-demographic characteristics of the Turkish migrants living in northern Italy. First, the majority of the participants (60% men and 40% women; sample size 544 individuals) reside in the Lombardy (Milan, Como, Lecco, and Varese), Emilia Romagna (Modena and Bologna) and Liguria (Imperia, Turin) regions (Figure 2).

Figure 2. Dots indicate locations of the majority of Turkish migrants.

- Socio-demographic characteristics

As for the age group of the participants, the highest number of participants was in the 25–34 age group with 38%, and this was followed by the 35–44 age group, with 29% (Figure 3). As for the employment status, 53% of the participants were employed full-time, 11% were students, and 17% were housewives, of which 95% came to Italy due to marriage (Figure 4).

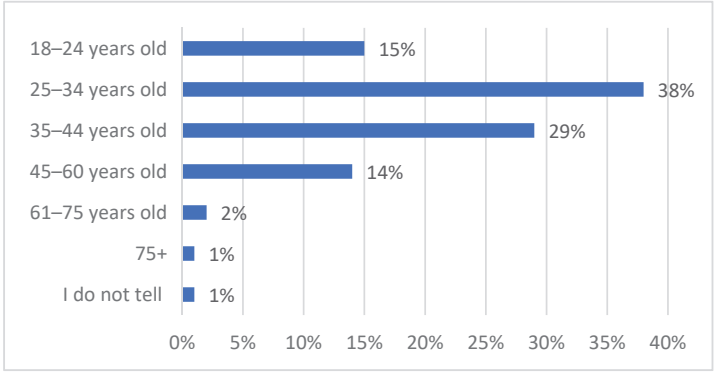

Figure 3. Age group of respondents of the questionnaire (sample size: 544 individuals).

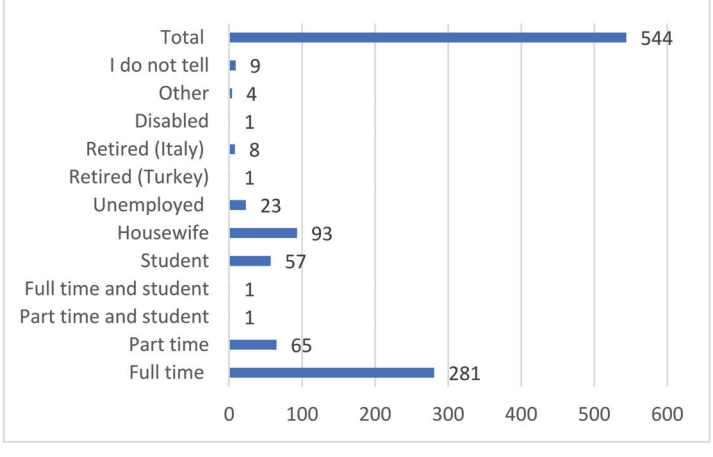

Figure 4. Employment status of the respondents (sample size: 544 individuals).

The majority of the participants were from Istanbul, Kahramanmaraş, Sivas, Çorum, Tokat and Ankara in Turkey. A great number of the participants have been residing in Italy for a long time. Overall, 38% of the population have lived in Italy for 10.1–20 years, while 35% have lived for 3.1 to 10 years (sample size: 544 individuals).

Regarding the educational status, the majority were high school graduates, with 30%, followed by elementary school graduates, with 27%. Some participants had never been to elementary school or had left elementary school. Among them, we encountered two illiterate women (sample size: 544 individuals).

The participants were asked questions to comprehend their level of linguistic skills. It was observed that all of the participants can communicate in Italian to various extents. Overall, 17% expressed their capability to handle daily tasks with the level of Italian that they speak, whereas 45% of the participants were confirmed to have a good understanding of the Italian language. Two participants were observed as being as non-Turkish speakers during the questionnaire. More than 40% of the participants can speak one more European language in addition to Turkish and Italian. The majority indicated English as the most widely spoken language among them. French, German and Spanish followed English in this classification (sample size: 544 individuals).

Furthermore, 79% of the participants declared that they speak another language, such as Kurdish or dialect, apart from Turkish, Italian and another European language (sample

size: 544 individuals). The participants stated that they speak Turkish, Italian and Kurdish sequentially in their homes. They strongly support the idea of multilingualism by bringing up multi-lingual children who can speak Turkish, Italian, Kurdish and at least one other European language (Figure 5).

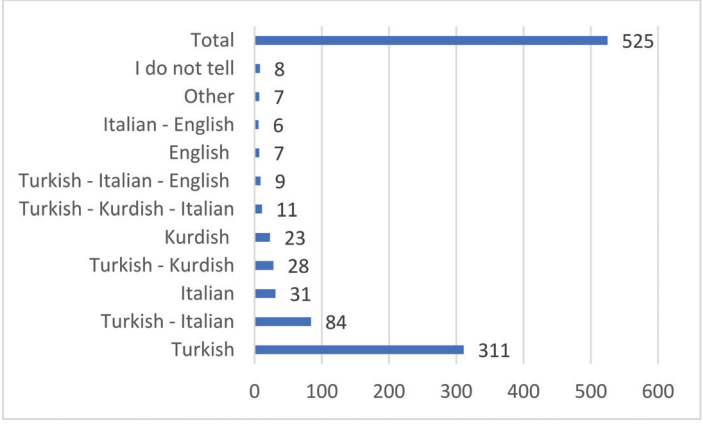

Figure 5. Languages that are spoken in households (sample size: 525 families).

- Disaster experience (sample size: 544 individuals)

Regarding disaster experience, 31% of the participants confirmed that they had experienced earthquakes and 4% had experienced floods in Italy to ranging extents. In all, 3% of the participants stated that they experienced both disasters (Figure 6). In particular, the participants from Modena and Milan had incurred monetary and property losses due to earthquake and flood disasters, respectively. One family mentioned that they did not ask for funding from the Italian government as they were not aware of such a mechanism. One person from Modena declared that many families living in Modena returned to Turkey after the occurrence of the Modena Earthquake in 2012.

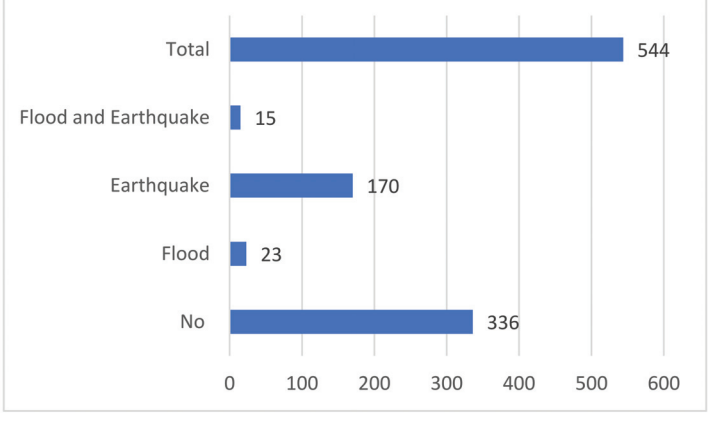

Figure 6. Whether participants have ever experienced flood and/or earthquake in Italy (sample size: 544 individuals).

Anxiety about natural hazards was identified in 63% of the participants. While 11% of the participants declared "excessive anxiety", 52% of them expressed "anxiety" in characterising their level of concern against disasters.

- Disaster preparedness (sample size: 544 individuals)

The majority of the participants were opposed to being self-prepared for disasters, propounding the lack of self-preparedness in Italian society. Even if the participants were quite conscious of the drawbacks of unpreparedness, surprisingly, the overwhelming majority were reluctant to take preventive actions. The participants who had been exposed to disasters in Turkey were perceived as being more susceptible and more predisposed towards the behaviour of "preparedness".

Only 23% of the participants informed their children about how to act during a natural hazard. Overall, 71% declared their ignorance about how to use "Fire Extinguisher" equipment. Meanwhile, 92% of the participants stated being self-conscious to switch on/off the gas, electricity, and water valves. In all, 87% expressed that they keep their important documents such as passports, insurance and deed papers in somewhat safe places. Overall, 83% of the participants admitted not having an "Emergency Kit" in their home, while 17% do have a "First Aid Kit". More than 50% of those maintaining a First Aid Kit confessed their ignorance in keeping the necessary medical supplies up to date.

- Potential behaviour of the respondents during disasters (sample size: 544 individuals)

Overall, 83% of the respondents declared not having planned where to reunite in case of an emergency. As a response to the "Where would you prefer going if you were supposed to leave Italy in case of a disaster?" question, while 64% of the participants indicated "Turkey", the remaining 36% answered "other cities of Italy or Europe" based on the relocation of their extended families.

- Disaster awareness (sample size: 544 individuals)

We presented seven disaster scenarios, including earthquake, flood, drought, snowstorm, pandemic, climate change and fire, to the participants. They were asked to classify them from the most probable (1) to the least (7). Participants declared "flood" as the most likely disaster to occur and "drought" as the least likely one in categorising the disasters for the area of interest.

- The most used communication media tool

With the help of this study, we wanted to raise the awareness of Turkish citizens about the risks of natural hazards in their vicinity and enhance their resilience in disaster risk management. For this reason, we asked participants a couple of questions to better understand the most common means of communication to convey "awareness-raising" messages. The responses of the participants showed that not everyone has a smartphone and continuous internet connection. The best means of communication was found to be "SMS" to deliver messages. The participants were asked which social media networks they use the most. More than 400 participants declared having a Facebook account and using it actively in their everyday lives. Therefore, a Facebook account was activated to inform the participants about the recent developments on the topic. We kept the Facebook account active for three years.

During the questionnaire, special topics on which the participants lacked sufficient information in disaster management were revealed, and informative leaflets were prepared to provide accurate information regarding these topics. The leaflets were distributed to the public in the General Consulate of Turkey in Milan. In addition to that, the researchers are currently in collaboration with "Search and Rescue Association" (AKUT) in Istanbul, Turkey, to provide the most accurate responses to the questions such as, "What is a family disaster plan? What are the essential components of an Emergency Kit? How to act during a flood?". The responses obtained from AKUT Team experts are published periodically as a series of videos via the project's Facebook page.

3.2. The Results of the Focus Group Meetings

The questionnaire revealed the spatial dispersion of the participants in northern Italy. Most of the population had been identified as settling down in Lombardy (Milan, Lecco, Como and Varese), Emilia-Romagna (Modena and Bologna) and Liguria regions (Imperia). Therefore, we decided to conduct focus group meetings in the Lombardy Region.

During the focus group meetings in Milano, Como, Lecco and Varese, all participants actively participated in the group discussion. We started each focus group meeting with the question of what a disaster is. The generally agreed on definitions are "loss of property", "loss of life", "material loss or damage", and the need for evacuation. During the focus group with women, they defined the disaster as "migration itself is a disaster" and "being prone to Islamophobia" (Table 2).

Table 2. Summary of focus group meetings.

Questions	Answers and Reactions
What is a disaster? Please specify.	Loss of property, loss of life, material loss or damage, the need for an evacuation, being a migrant, Islamophobia
Do you think that an environmental disaster will happen to you?	Most of them said no. There was a difference between the ones who had already experienced an earthquake or flood event and the ones who had never experienced one
During an emergency/disaster, what would be your priorities?	For mothers, their children and reaching out to husbands; for male participants, calling 112 to understand what's happening; for students, reaching for their passports and cash
During an emergency/disaster, what may you need?	The majority answered that they need to understand what has been happening and safe areas
Who do you call first?	Female participants call their husbands; male participants call 112; and students call 112 and their families in Turkey
During an emergency/disaster, how do you reach the information that you need?	Asking my neighbour/friend and family member or calling 112. Participants were not aware of any of the information websites that we shared with them
(Information resources covering the regions that they are living were shown to the participants in terms of visual materials and was asked) Do you know these sources of information?	All of them said no
How would you be aware of these resources? How do they reach you?	Social media (Facebook) and SMS
What can you do to protect yourself and your family from a disaster?	The participants in the Varese focus group meeting were very well prepared
If you experience a disaster/catastrophe, will you go back to Turkey?	The participants discussed this question, and their final answer was a "yes".

Most of the participants had experienced an earthquake or a flood event in Turkey or Italy. Most of the participants stated that a disaster could happen at any moment; some had a fatalistic approach. The participants in Varese experienced the 1999 Izmit earthquake in Turkey, and one of them was in the earthquake's epicentre. They were still feeling the impact of the event. This group's awareness level was the highest, and they conducted several emergency drills at their home with their children.

It was clear that the priorities during an emergency and reactions to the situation change according to gender, age, and family presence. The first reaction of women was bringing the family together; the first reaction of men was to understand what's happening and the extent of the disaster. On the other hand, all students said that the first thing they would do is reach out for their passports and cash.

Most of the women are dependent on their husbands and do not speak Italian. This linguistic incapability creates a barrier for adaptation, isolates them from local society and

increases their vulnerability. They seek word of mouth information and communicate with their neighbours or friends who speak the same language. The focus of mothers is their children. They told us that, first, they would seek their children, and after finding them, they would call their husbands for help.

On the other hand, migrants are tightly connected. Their social network is the main resource, especially those isolated due to the language barrier. However, it is still not possible to conclude that the strong sense of community provides resources that make them resilient in the long run, as in some cases, being isolated might be a barrier to reaching out for essential information and resources.

4. Discussion

The "City, Migration and Disaster" study was set out to explore the environmental disaster risk awareness of the Turkish community living in the region, as well as their socio-demographic structure. Indirectly, in practice, the study raised awareness of the Turkish migrants and referred them to sources to increase their knowledge and awareness of disaster risk.

Similar to findings from other research, our study confirms a lack of preparedness and a more general lack of interest in preparedness actions. This is aligned with the "invisible" framing arguments [9,10] and can be related to a lack of involvement in disaster decision making processes. This causes a low level of awareness despite the participants living in Italy, which is a country prone to natural disasters, for 10–20 years. Notwithstanding low interest in preparedness, the level of risk awareness with regard to natural hazards seems quite high, since floods and earthquakes were deemed as the most probable risks.

Additionally, our study confirms the role of past experiences in disasters, since the participants who were exposed to disasters in Turkey are perceived being as more susceptible and more predisposed towards the behaviour of "preparedness". However, as shown by Becker et al. [32], the experience–preparedness relationship is a complex one, and may differ in relation to hazards and the socio-economic status of the person. Nonetheless, the importance of past experiences cannot be underestimated, as it is a determinant of future actions and of reslience as well [33–35]. The importance of having a multi-faceted approach was also confirmed, as gender and cultural differences seemed to emerge: for instance, concerning gender differences and priorities during the response phase. Moreover, as stated in the introduction, such an approach would be a pre-condition for ensuring proper inclusion in disaster risk reduction (DRR). This seems to be corroborated (even if indirectly) by answers to questions about disasters in general. For "what is a disaster", most of the respondents did not mention a specific hazard but rather referred to, e.g., "migration", "Islamophobia". DDR policies should take into account socio-cultural differences in perceiving disasters.

In line with the findings of this study, we do not seek to label migrants as 'vulnerable', as they have unique capacities that could increase their resilience. The results confirm the studies of Fussell et al. [12] and Guadagno et al. [21], proving that social networks can be a resource in a disaster for migrants. If social capital is important, social competence is also crucial to enhance resilience. In the focus groups, social compentence emerged in relation to the priorities and needs during an emergency, since male participants would rightly call 112. The discussion in the focus group meetings was in line with the Uekusa and Matthewman [20] study that stated that struggling with the existing inequalities in their daily lives makes migrants resilient. Overall, the results of our study show that there is a high potential for resilience that seems to emerge through some key resilience dimensions that vary from prior experiences with disasters to social capital and competence.

It is also possible to relate the findings of this study with coping mechanisms for trauma. During the focus group meetings, we observed that participants tend to make decisions based on their previous experiences and having a family or not. Additionally, not being attached to the place provides them with the freedom to move in the case of a disaster, but being a part of a close-knit community is one of the main mechanisms to cope

with disasters such as floods and earthquakes. More studies can be conducted to relate the findings further with the "Nudge Theory" to improve the resilience of migrants [36–38]. The findings from our study suggest that understanding cultural barriers is key for disaster preparedness. Without proper linguistic skills, it is impossible to ensure disaster preparation across all phases of the disaster cycle (mitigation, preparedness, response and recovery).

5. Conclusions

In this study, we investigated the socio-demographic characteristics, risk awareness, participation in development, prevention and mitigation strategies, education programs, capacity to invest in mitigation, access to flood information and training/experience of the population, perception and awareness of risk condition, awareness of education programs, individual preparation, and understanding of the ways to access flood information among the Turkish migrants living in the area.

In this study, our target group was legal migrants older than 18 years old. However, some marginal groups might be more vulnerable than our samples, such as illegal migrants and close-knit communities that we could not reach out to to conduct focus group meetings. We completed 544 questionnaires with respondents living in nine regions in northern Italy. We limited the geographical focus to the Lombardy region during the focus group meetings because of the high number of Turkish migrants living in the area. The survey was conducted in 2015; the results presented here might be considered "old", but the results can inform future studies on the Turkish community in other European countries. Researchers may benefit from the methodological approach and the findings. For instance, policymakers may be interested in understanding socio-cultural dimensions that should not be overlooked in DRR processes and policies. Moreover, the results are aligned with the findings of previous studies in other countries.

The project succeeded in drawing great attention from both the affiliated institutions and the public, who voluntarily and actively participated in each project stage. It was carried out mainly in the Lombardy region due to limited time and resources. Nevertheless, the project has the opportunity to be extended to cities such as Modena and Imperia, where a remarkable Turkish population that needs to be informed about earthquake and flood risks in their area of settlement is present. Moreover, the project offers insights for further research on the Turkish communities in other European countries. The recent flood events in July 2021 in Belgium, the Netherlands and Austria proved the importance of conducting such studies in hazard-prone areas with a large number of migrants.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. The consent forms were in Turkish. We had two participants who required translation of the documents to Italian, and we translated all the documents for them to Italian. The consent form explicitly stated that participation is voluntary. Anyone has the right to refuse to participate and to withdraw their participation, samples or data at any time without any consequences. Participants gave their consent by signing a separate form from the questionnaire, as the questionnaires were anonymous.

Data Availability Statement: We did not collect more data than were necessary to reach the research goal. All data were handled in a manner that respected the rights specified in the agreements (informed consent and transfer of intellectual property). Collected data is anonymized and not open source. The data report was prepared in Turkish and submitted to the funding body at the end of the project.

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Appendix A

Codes to read the tables: FT-E: full-time employment; PT-E: part-time employment; HW: housewife, S: student; UnEmp: unemployed; MSc S.: Master of Science student; Uni.: university; HS: high school, PS: primary school; SS: secondary school; Int: intermediate; EN: English language; DE: German language; AR: Arabic language; S: single; M: married; y: years.

Table A1. Coding of the participants of focus group I in Lecco.

Participants' Code	L1P1	L1P2	L1P3	L1P4	L1P5	L1P6
Gender	Male	Female	Male	Female	Female	Male
Age group	18–24	18–24	18–24	25–34	25–34	25–34
Occupancy	MSc S.	MSc S.	MSc S.	MSc S.	MSc S.	MSc S.
Education	Uni.	Uni.	Uni.	Uni.	Uni.	Uni.
Marital status	Single	Single	Single	Single	Single	Single
For how long have you lived abroad?	2 months	2 months	2 months	1 y.	1 y.	1 y.
For how long have you lived in Italy?	2 months	2 months	2 months	1 y.	1 y.	1 y.
Is your family in Italy?	No	No	No	No	No	No
What level is your Italian language?	None	Int.	None	Basic	Good	Int.
Do you speak another language, except Italian and Turkish?	EN	EN	EN	EN	EN, DE	EN

Table A2. Coding of the participants of Focus Group 2: women residing in Milan.

Participants' Code	M2P1	M2P2	M2P3	M2P4	M2P5	M2P6	M2P7	M2P8	M2P9
Gender	Female	Female	Female	Female	Female	Female	Female	Female	Female
Age group	18–24	25–34	25–34	45–60	18–24	35–44	35–44	45–60	25–34
Occupancy	S.	FT-E	HW	PT-E	HW	HW	FT-E	HW	HW
Education	HS	PS	HS	PS	HS	PS	PS	PS	HS
Marital status	S	M	M	M	M	M	M	M	M
For how long have you lived abroad?	Born in Italy	11 y.	8 y.	30 y.	2 y.	20 y.	19 y.	23 y.	8 y.
For how long have you lived in Italy?	Born in Italy	11 y.	8 y.	30 y.	2 y.	20 y.	19 y.	23 y.	8 y.
Is your family in Italy?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
What level is your Italian language?	Native	Basic	Basic	Int.	None	Basic	Basic	Int.	Basic
Do you speak another language, except Italian and Turkish?	No	No	No	No	No	No	No	No	No

Table A3. Coding of the participants of Focus Group 3: men residing in Milan.

The Code of the Participant	C3P1	C3P2	C3P3	C3P4	C3P5	C3P6	C3P7	C3P8	C3P9
Gender	Male	Male	Male	Male	Male	Male	Male	Male	Male
Age group	45–60	35–44	18–24	45–60	45–60	18–24	75+	45–60	25–34
Occupancy	FT-E	FT-E	FT-E	Retired	UnEmp	Stdn.	Retired	FT-E	FT-E
Education	PS	Uni.	HS	PS	PS	HS	PS	Uni	PS
Marital status	M	M	S	M	M	S	M	M	M
For how long have you lived abroad?	25 y.	20 y.	2 y.	28 y.	20 y.	8 y.	40 y.	13 y.	4 y.
For how long have you lived in Italy?	25 y.	11 y.	2 y.	27 y.	20 y.	8 y.	40 y.	13 y.	4 y.
Is your family in Italy?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
What level is your Italian language?	Good	Int.	Int.	Good	Good	Good	Good	Int.	Int.
Do you speak another language, except Italian and Turkish?	No	AR, EN	No	No	No	No	Greek	No	No

Table A4. Coding of the participants of Focus Group 4/1 families residing in Lecco.

The Code of the Participant	L4P1	L4P2	L4P3	L4P4	L4P5	L4P6	L4P7	L4P8
Gender	Female	Female	Female	Male	Male	Male	Male	Male
Age group	25–34	35–44	25–34	35–44	45–60	45–60	35–44	35–44
Occupancy	HW	FT-E	FT-E	PT-E	FT-E	FT-E	FT-E	FT-E
Education	ES	PS	HS	PS	PS	Uni	PS	HS
Marital status	M	M	M	M	M	M	M	M
For how long have you lived abroad?	5	18	14	10	18	20	15	14
For how long have you lived in Italy?	5	18	14	10	18	20	15	14
Is your family in Italy?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
What level is your Italian language?	Int.	Basic	Good	Int.	Int.	Int.	Int.	Int.
Do you speak another language, except Italian and Turkish?	No	No	No	No	No	No	No	No

Table A5. Coding of the participants of Focus Group 4/2 families residing in Lecco.

The Code of the Participant	L4P9	L4P10	L4P11	L4P12	L4P13	L4P14	L4P15	L4P16
Gender	Male	Female	Male	Male	Female	Female	Male	Male
Age group	25–34	35–44	45–60	35–44	35–44	35–44	45–60	35–44
Occupancy	FT-E	FT-E	FT-E	FT-E	PT-E	PT-E	FT-E	FT-E
Education	HS	HS	SS	PS	HS	SS	PS	SS
Marital status	M	S	M	M	M	M	M	M
For how long have you lived abroad?	13 y.	18 y.	15 y.	17 y.	13 y.	12 y.	25 y.	22 y.
For how long have you lived in Italy?	13 y.	18 y.	15 y.	17 y.	13 y.	12 y.	25 y.	22 y.
Is your family in Italy?	Yes	-	Yes	Yes	Yes	Yes	Yes	Yes
What level is your Italian language?	Good	Good	Int.	Good	Int.	Int.	Good	Int
Do you speak another language, except Italian and Turkish?	No	No	No	DE	No	No	No	No

Table A6. Coding of Focus Group 5: Researchers working at an international research organisation and their families residing in Varese.

Participants' Code	V5P1	V5P2	V5P3	V5P4	V5P5	V5P6	V5P7	V5P8	V5P9
Gender	Female	Male	Female	Male	Female	Male	Male	Female	Male
Age group	25–34	35–44	35–44	35–44	35–44	35–44	35–44	45–60	45–60
Occupancy	FT-E	FT-E	PhD C.	FT-E	HW	FT-E	FT-E	Retired	FT-E
Education	PhD	MSc	MSc	PhD	MSc	PhD	PhD	Uni	MSc
Marital status	M	M	M	M	M	M	S	M	M
For how long have you lived abroad?	2 y.	2 y.	5 y.	5 y.	5 y.	5 y.	4 y.	3 y.	3 y.
For how long have you lived in Italy?	2 y.	2 y.	1 y.	1 y.	5 y.	5 y.	4 y.	3 y.	3 y.
Is your family in Italy?	No	Yes	Yes	Yes	Yes	Yes	-	Yes	Yes
What level is your Italian language?	None	None	Int.	Int.	Int.	Int.	Basic	Int.	Basic
Do you speak another language, except Italian and Turkish?	EN	EN, ES	EN, ES	EN, ES	EN	EN	EN, DE	EN	EN

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Article

Crisis Communication after Earthquakes in Greece and Japan: Effects on Seismic Disaster Management

Anna Fokaefs * and Kalliopi Sapountzaki

Geography Department, Harokopio University of Athens, 17676 Kallithea, Greece; sapountz@hua.gr
* Correspondence: afokaeus@hua.gr; Tel.: +30-6974456303

Abstract: The communication of emergency information shortly before or after the manifestation of seismic hazards is a crucial part of disaster management. Crisis communication aims to protect, support and guide the public and emergency services throughout the response and recovery phase. In the case of seismic events, a fundamental query refers to how the information to be released to the public immediately after/before the seismic event affects disaster impacts and management. This paper addresses the uncertainty involved in emergency seismic information, identifies the sources, means, content and mode of emergency communication and points to the effects of different models of crisis communication on public perceptions, on emergency responses and, hence, on disaster management. A review of past experiences of seismic crisis communication strategies in earthquake-prone countries, namely Greece and Japan, reveals successes and failures in managing uncertainty, and in building public trust and improving response capacities. The findings include the importance of crisis communication in seismic disaster management, the levels/layers of uncertainty involved in emergency seismic information and how they impact risk perceptions, the public trust/mistrust effect on scientific and management institutions as well as some recommendations for seismic crisis communication strategies to minimize uncertainty and improve emergency responses.

Keywords: seismic crisis; seismic emergency information and communication; uncertainty; risk perception; governance culture; Greece; Japan; seismic risk management

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1. Introduction

The short period (of a couple of weeks) following the initial strong tremors of a seismic event is a crisis period with a state of emergency. This is confirmed by the several conceptions and definitions of a crisis: (a) events potentially leading to unstable and dangerous situations affecting individuals, groups or communities [1]; (b) events or series of events that are non-routine and unexpected, creating high levels of uncertainty and a threat or perceived threat to a community's high priority goals [2]; (c) harmful and disruptive or threatening events for organizations and communities potentially implying negative changes in security, economic, political, societal or environmental affairs, especially when they occur with little or no warning [3–6]. In general, experts and scholars view crises as "testing times" or "emergency events" wherein immediate responses are an imperative. However, immediate responses of the public and responsible organizations in crisis contexts—featured by unknown situations and destabilization of the usual frames of reference [7]—presuppose an intense flow of emergency information. Consequently, "crisis communication" in the present paper is associated with the emergency phase of the (seismic) disaster (and risk) management cycle and the need to inform and alert the public and managers about an already damaging and/or potentially harmful event. It has been suggested that the content, mode and timing of crisis/emergency communication "may either reduce and contain the harm or make the situation worse" [8].

Crisis communication in the case of earthquakes overlaps with risk communication, but the two forms of communication are not interchangeable because: (a) risk communication spans every phase of the (disaster) risk management cycle, not only the emergency;

(b) emergency communication refers to mixed information containing facts and data on the one hand and uncertain predictions and advice on the other; (c) in emergency (and not risk) communication, decisions must be made within a narrow time constraint on the basis of imperfect or incomplete information, and these decisions may be irreversible and their outcome uncertain. This mixture of certain (about the immediate past) and uncertain information referring mainly to the predicted evolution of the extreme phenomenon, secondary hazards and damaging impacts, as well as recommended responses, has an intermediary, tentative character, meaning that it is subject to constant updating. Since this provisional information leaves room for opposing views/predictions, it can easily lead to confusion in public perceptions and actions. Only socially/politically acceptable and trustworthy information sources can counteract the chaotic situation that may emerge from a cognitive crisis on top of a post-earthquake crisis [9,10]. Indeed, in the case of strong catastrophic earthquakes, the general public and emergency managers seek credible scientific information (i.e., announcements of magnitude, location, damage and secondary effects, the possibility of aftershocks, advice and guidelines for responsive action) among several sources: geoscience information centers, public administration agencies, health–welfare agencies, individual experts and mass and social media.

Uncertainty is a key factor of (seismic) crisis communication [11], and while it can generate mistrust and confusion, it may also advocate information seeking [12,13]. However, eagerness and anticipation for information supply are time limited and strongly dependent on the (seismic) disaster magnitude [14].

There are several types of uncertainty involved in seismic emergency information originating from the different types of messages being aimed at emergency managers and the general public [15]:

- *Informative messages*, reporting earthquake parameters (magnitude and epicenter); these are released near real time after the earthquake. Messages regarding injuries or damages to infrastructure (e.g., building collapses) several minutes up to hours after an earthquake are also informative. This information is continuously updated.
- *Warning messages* about other secondary effects and their characteristics (e.g., tsunamis, landslides etc.). This information follows (and is based on) the initially resealed messages about earthquake parameters. Forecasting of aftershocks also belongs to this category. When (and where) earthquake early warning practices are established (e.g., Japan and the USA), alerts are issued in order to warn the public and systems a few seconds before the destructive shaking.
- *Consulting messages* about the appropriate safety measures and actions to be undertaken (e.g., going to open areas or moving to higher places and for how long). This information is available shortly after an earthquake and is also continuously updated.
- *Guiding messages* regarding instructions on assistance retrieval, refuge spaces, evacuation routes, health facilities, emergency telephone numbers etc. This information is available usually a few hours after an earthquake and it is updated continuously.

The information released within the first minutes following the event carries background uncertainty due to limited knowledge and incomplete data, which are constantly updated/revised as the event evolves, thus adjusting/(re)forming the content of the consulting and guiding information (e.g., evacuation). Indeed, the initial information reporting earthquake parameters is based on preliminary estimations and measurements, and is often non-precise or incomplete. On the other hand, the initial warnings (e.g., possibility of tsunami generation or aftershock occurrence) are based on computed database scenarios or on simplified methodologies and seismicity catalogue elaboration rather than direct observations. In particular, in the case of earthquake predictions, these are mainly based on precursory phenomena (e.g., ground deformation, geo-electric anomalies and abnormal seismic activity). Uncertainty however, is not only epistemic, it may also come from the different perceptions or multiple knowledge frames of people and managers (as affected by preparedness levels besides), thus leading to different attitudes or interpretations of consulting and instructive messages. Apart from the uncertainty related to the phenomenon,

scientific knowledge and risk perceptions, coordination and governance issues (related to the implementation of instructive messages) and technology limitations and failures add layers of uncertainty.

In summary, uncertainty in seismic emergency periods originates from both the probabilistic information released by scientific institutions and the situation of the crisis itself, leaving the public puzzled with questions: What are the causes of the crisis and how long will it take to return to normality? Who is responsible for crisis management, and where do the protection measures come from? While people often want clear and quick answers in order to make sense of the situation and make decisions on actions to take to protect themselves, it is often difficult for emergency managers to meet these information needs. The crisis might still be unfolding, the full scale of the disaster may still be unknown and the collection and elaboration of empirical data may take a long time to become useful information to be communicated with the public.

2. Research Queries, Scientific Background and Methodology

2.1. Scope and Research Queries

While there is a sizable body of research on best practices in risk and crisis communication, and despite acknowledgement of the crucial role of uncertainty, there is a theoretical gap on good practices and principles for communicators to manage crisis information uncertainty [16]. The authors, aspiring to generalizable principles for seismic crisis communication, attempt to conduct comparative empirical research on two country cases of the developed world featured by distinct risk cultures (Greece and Japan). The ultimate objective is the handling of uncertainty to the best outcome of disaster management. Relevant research queries are as follows: (a) What layers/levels of uncertainty are involved in seismic emergency information released to the public? (b) How do these uncertainty layers relate to the source, content, channels and modes of seismic crisis communication? (c) What is the impact on public perceptions and responsive actions? (d) How are crisis emotions and management failures related to uncertainty? (e) What are "acceptable" levels of uncertainty, and how does uncertainty management predict seismic emergency and disaster-related outcomes? The following paragraphs map current and incomplete theoretical knowledge regarding interrelations between seismic crises, seismic emergency information and communication, uncertainty, risk perception and risk cultures as well as emergency responses.

There are two basic challenges in managing seismic emergency information uncertainty: First, to deal with epistemic uncertainty and secondly, to deal with uncertainty involved in emergency communication (owing to diverse risk perceptions and knowledge frames, governance obstacles and technological limitations). The present work focuses principally on the second challenge.

2.2. Dealing with Uncertainty in Scientific Seismic Infomration

Every form of prognostic and probabilistic information about a seismic event that has or has not already started includes many levels of uncertainty. According to [17], these "range from the natural stochastic uncertainty ("aleatory"—the variability of the system) to the epistemic uncertainty (meaning lack of knowledge), also from scientists being uncertain about their knowledge and data, through to disagreement amongst scientists . . . " In hazard assessments, aleatory uncertainty is treated probabilistically and epistemic uncertainty is treated by various mathematical models (Figure 1). In Seismic Hazard Assessment, aleatory uncertainty is typically represented by probability distributions and epistemic uncertainty is represented by weighted alternative assumptions in logic-tree approaches. Some key approaches in handling uncertainty will be mentioned but providing a detailed survey of the related literature is beyond the goals of the present paper.

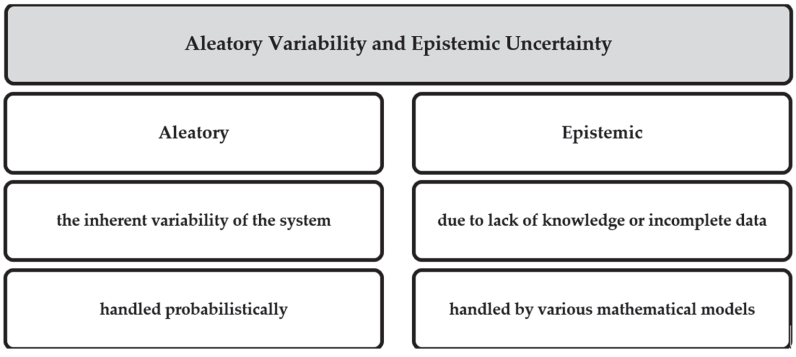


Figure 1. Scientific uncertainty classification and quantification practices. Source: authors' elaboration.

Regarding the parameters of initial earthquake announcements, especially the quality of magnitude determinations, it is expressed by statistical techniques mainly by standard error estimations. The next concern is about the possible aftershocks. Aftershock forecasting and the uncertainty involved are handled by various statistical approaches, e.g., the epidemic-type aftershock sequence (ETAS) model [18,19] and the stress release model developed by [20]. A characteristic example is the operational aftershock forecasting in New Zealand [21] following the Canterbury Earthquake Sequence: The expected number of different magnitude earthquakes and/or ground shaking for specified time periods have been released to the public and key stakeholders as tables, charts and maps and the relative uncertainties were expressed by probability distributions.

Probabilistic Seismic Hazard Assessment (PSHA) is considered to be in the first line of defense in mitigating seismic risk [Field and Milner 2018]. It is well documented in the literature that PSH maps carry both types of uncertainty [22–24]: (1) aleatoric uncertainty associated with seismic wave propagation, treated by the standard deviation of the attenuation relation and (2) epistemic uncertainty related to the characteristics of seismic zones, earthquake recurrence rate and maximum earthquake magnitude. PSHA outputs are communicated to decision makers and the public in forms of seismic hazard contour maps or hazard curves where the uncertainty is illustrated as the probability that a given site will experience ground motion intensity exceeding a certain value within a target period. A characteristic example is Japan (see Section 3.2.1) Application of this method for PSHA in N.E. Italy is analyzed in [25].

Accordingly, in the Probabilistic Tsunami Hazard Assessment (PTHA), the probability of exceeding specific levels of tsunami intensity metrics (e.g., run-up or maximum inundation heights) in time and space is illustrated in hazard maps or hazard curves. Epistemic uncertainty relates to earthquake rupture processes, while inundation or run-up processes involving the resolution and accuracy of bathymetry and digital elevation models have a significant impact [22]. In the case of a real earthquake event (Tsunami Early Waning, TEW), the alert level and tsunami impact estimation are based on pre-simulated scenarios. The dominant uncertainty in TEW as well as in long-term PTHA originates from the preliminary seismic information [26]. One way to handle this source of uncertainty is by adopting the maximum possible earthquake magnitude generating the maximum probable tsunami wave [27]. Another way is to use the PSHA outputs to tsunami simulations [28].

Finally, SHA is usually combined with the vulnerability characteristics of buildings in order to obtain the degree of probable structural damage [29]. The developed approach for vulnerability assessment in Europe is based on the vulnerability index method: different vulnerability classes are assigned to different building typologies. Rapid Visual Screening Assessment methods is another popular empirical approach for rapid vulnerability assessment. On the other hand, analytical methods (Non-Linear Time History Analysis and Non-Linear Static or Pushover Analysis) can handle all kinds of uncertainty in de-

termining the level of damage to structural elements. Modeling the behavior of critical structures due to earthquake load contributes significantly to the post-earthquake damage assessment [30,31].

2.3. Uncertainty Communication in Seismic Crisis Periods

As made evident in the Introduction and acknowledged in the literature, "crises are by definition high-uncertainty events, where information is often not immediately available" [11]. This is also true for seismic crises, because the information released immediately after the first strong tremors (should it reach the exposed population) always falls short of the public's information requirements. For instance, first announcements through the mass media usually refer to the magnitude and epicenter of the initial event but not to other types of information most critical for the population affected or to be affected: anticipated frequency, time and magnitude of after-shocks, geographical extent of the hit area and locations of probable building collapses, number and location of people injured, safe and unsafe buildings to stay inside or evacuate, damages and the period of time needed for recovery and re-operation of the disrupted electricity and mobile communication systems etc. These information gaps will most likely be covered much later, leaving the affected population under a condition of uncertainty for a long period of time.

The problem involves information gaps creating uncertainty in a crisis period, especially when threatening conditions are evolving, and the authors of [32] suggest that "the immediate communication needs during a crisis are to reduce uncertainty allowing audiences to create an understanding of what happened so that they may respond appropriately" (see also [16]).

The description of the condition of uncertainty in [33] seems broad and encompassing of all versions of (seismic) emergency information deficit: "uncertainty exists when details of situations are ambiguous, complex, unpredictable, or probabilistic; when information in demand is unavailable or inconsistent; and when people feel insecure about their own state of affairs and state of knowledge in general".

According to [16], to date, there is no known crisis communication theory that explicitly addresses uncertainty. Several crisis communication theories relate to uncertainty but do not clarify how communicators should integrate uncertainty into their work. The only theories of communication uncertainty exist outside of crisis research. The most well-known are the uncertainty reduction theory, the uncertainty management and the problematic integration theory. The first, originating from the work of [34], considers uncertainty as the number of possible outcomes of a situation, and it is based on the assumption that humans are motivated to decrease uncertainty about themselves and others. From this perspective, uncertainty is an adversity, something that should always be mitigated. It has been criticized in that it does not consider the modeling of unusual, multifaceted communication situations that are commonplace in crisis periods. Researchers have responded to this criticism by adding moderating variables, such as culture.

The adherents of the second theory [35], i.e., uncertainty management theory, argue that people experience uncertainty in different ways and not only as a negative situation that should be reduced. Depending on the cultural context and other factors, uncertainty may be positive, neutral or negative. In particular, [16] quotes the argument of [36] that people may opt to seek information to increase uncertainty and of [37] that people may avoid information altogether to maintain hope and optimism. The third, i.e., problematic integration theory, adopts the view that information seeking can resolve uncertainty but adds that information may be unavailable [38]. The theory refers, in particular, to difficult conditions of mismatch between information demand and supply, which are well-fitted to the seismic crisis context: affected people may not know when information will be available, whether the desired information will be available by when they need it and whether knowing the information will matter to them personally.

Uncertainty interrelates with trust, while public trust depends on the sources and means of communication of emergency information. The authors of [39] cited in [16] argue that "the more the public put trust on government or the communicating institutions, the better they are able to handle fear and panic in crisis contexts . . . For this reason it is better for the official communicators to admit uncertainty than to present information as certain and be proven wrong later". Emergency communication cannot be successful without the public's trust in message sources; previous errors, such as releasing false information, may decrease public trust in information-releasing institutions.

Matters of complexity, uncertainty and trust arise not only among the public receiving information from scientific institutions and official communicators but also among official institutions and emergency managers when facing huge quantities of data and information originating from social media platforms. In the chapter titled "Decision-making under uncertainty", the authors of [40] argue that technological progress has enormously increased the lay public's connectivity and continues to promise broader bandwidth and unknown computational power to all (see also [41]). These authors argue that the use of social media that first gained acceptance in the Haiti earthquake has become "mainstream" since then. Moreover, technology-driven data sources, such as GPSs, radiofrequency-based identification tracking, remote sensing, satellite imagery and drones, enable real-time monitoring [42]. The various data extracted from sources ranging from sensors to social media are fraught with different types of uncertainty. Therefore, not only have scientists lost the exclusivity to create and disseminate seismic crisis information, but they have to prove that their approach, data collection and advice match the purpose and context of the specific crisis in question.

Finally, seismic crisis communicators should consider power dynamics in their approach to uncertainty. The authors of [40] suggest that seismic or other crisis information holders can strive to maintain asymmetrical levels of information access and uncertainty to gain power over others. As an example, preventing relief actors from collecting information on humanitarian needs has proved to be a means for authoritarian political regimes to retain power during and after crisis periods.

Consequently, the content and sources of emergency information and means of communication and information exchange between scientific institutions, governmental and non-governmental managers and the public affect the levels of uncertainty and trust in the crisis context.

The authors conducted empirical research on seismic crisis communication strategies, norms and practices to identify their impact on the dynamics of the crisis in two earthquake-prone countries, namely Greece and Japan. This is a comparative analysis of (a) the sources of emergency information and the process of transmission, (b) the types of uncertainty involved and (c) the content of messages including uncertainty handling . . . The comparative analysis was carried out during two distinct chronological periods: the normal period and the emergency period. The first was accommodated by an analysis/review of the administration structures responsible for seismic crisis communication and management in the two countries and the legislations governing the flow of emergency information (Section 3). Additionally, semi-structured interviews with key informers and online questionnaires to key audiences in Greece were used to address seismic risk perceptions, information needs and trust of the respondents in the authorities. The second, i.e., the analysis in the emergency period (Section 4) was a test on how the crisis communication strategies/patterns of the two countries work in practice. Section 4 is composed of case studies of actual seismic crisis events to elevate communication successes and failures. Section 5 offers a discussion on the causal relationships between the basic factors connecting seismic crisis communication with emergency management: handled or unhandled uncertainty, risk perceptions, administration structures and cultures, trust deficits and probable secondary crises (cognitive or other). Section 6 is devoted to conclusions and recommendations. The analytical methods employed (apart from the reference to the statistical methods used for the determination of scientific seismic uncertainty) are a combination of qualitative

and quantitative approaches pertinent to political science and communication research: Content Analysis of seismic information messages, (Institutional) Process Tracing of seismic information transmission, semi-structured Interviews, Questionnaire Surveys and test Case Studies of crisis experiences (in Greece and Japan).

3. Sources, Types and Modes of Emergency Communication of Earthquake Information: Greece and Japan

3.1. Greece

3.1.1. Public Administration Agencies as Emergency Information Sources and Crisis Management Authorities

The basic public body at the national level responsible for emergency management in Greece in cases of strong and damaging seismic events is the General Secretariat of Civil Protection (GSCP), a subdivision of the Ministry of Citizen Protection. All responsibilities of the public bodies at central, regional and local levels are described in detail in national level official plans (Xenokratis General Plan and Egelados Plan. For more details, visit https://www.civilprotection.gr/, accessed on 1 February 2021). In the event of a damaging earthquake, GSCP announces earthquake reports regarding the event's parameters (retrieved by the Geoscience Information Centers—see Section 3.1.2) with guidelines for self-protection. Instructions on where to address help requests are also publicized. This information is released to the public through GSCP's official website, official social media accounts and breaking news on TV. Rescue and rehabilitation operations, humanitarian support and informing the public about relevant issues are coordinated and monitored by GSCP in close collaboration with the local authorities. In emergency periods, the local and regional coordination centers have the upper hand regarding emergency management decisions and accordingly communicate appropriate actions, such as evacuation orders and declaration of emergency. During the critical minutes shortly after the seismic disaster, the size of the impact is (almost) unknown (high epistemic uncertainty). It is only after the rescue services, police and fire service as well as media representatives reach the affected areas that the needs for coordination and operational actions become clear. However, the arising challenge is addressing the ambiguity due to multiple ways of interpreting the mostly unspecific instructions. An additional layer of uncertainty may come from the interruption of telecommunication services (telephone and mobile network).

At the same time, the policy for seismic protection in Greece is drafted and coordinated by the Earthquake Planning and Protection Organization (EPPO), supervised by the Ministry of Infrastructure, Transport and Networks. EPPO's main objectives and actions are: to provide and disseminate information for the prevention, preparedness and management of seismic risk/disaster; to increase awareness and seismic risk education of the population; and to strengthen the seismic capacity of building structures. In the case of a strong earthquake, EPPO provides an initial evaluation of the earthquake's impact and building damages after communication with the local police departments (by telephone) and by organizing on-site visits to the areas. Similar to GSCP, the lack of knowledge characterizing the first minutes after the seismic event and technical problems such as network service failures enhance uncertainty.

EPPO is supported by the Permanent Special Scientific Committee for the Assessment of Seismic Hazard and the Evaluation of Seismic Risk (PSSC). PSSC is responsible for the assessment of the seismicity during the seismic crisis—including persistent seismic activity recorded in a particular area, e.g., swarms—and the possibility of aftershock occurrence, as well as evaluation of the submitted short-term and long-term earthquake predictions by organizing ad-hoc meetings with panels of scientists, policymakers and local first responders. The panel is composed of science advisers, decision makers and emergency managers, reflecting different knowledge backgrounds, needs and perspectives. Consequently, seismic information carries partial knowledge, ambiguity due to conflicts and inherent variability. The conclusions and recommendations of PSSC meetings after a seismic crisis are released to the public through the official webpages of EPPO and

GSCP, traditional media (TV and radio), social media and news websites. To date, not one earthquake prediction has been communicated by PSSC members to the public in Greece.

The Institute of Engineering Seismology and Earthquake Engineering (ITSAK) is a research unit of EPPO operating a strong motion network (accelerometers) installed in major Greek cities. ITSAK releases automatic ShakeMaps, which are widely used to illustrate the ground motion and shaking intensity following significant earthquakes. The uncertainty of these automatic ShakeMaps is related to the preliminary earthquake parameters (epistemic uncertainty). As soon as real-time strong motion data are delivered and revised and macro-seismic observations of the effects are available, the ShakeMaps are updated. GSCP and EPPO perform close collaboration during earthquake crisis in terms of participating in PSSC emergency meetings and realizing common/parallel on-site visits for evaluation of the earthquake impact.

At the regional and local (municipal) level, the Directorate of Civil Protection and the Municipal Office for Civil Protection exercise prevention, preparedness, risk communication and recovery competences. The municipalities affected by the seismic crisis, after communication with the local responders, gather information on earthquake damages or other induced phenomena and inform the Regional Administration in order to coordinate and prioritize the civil protection actions at the local level. The uncertainty involved in the emergency information released is reduced as long as more knowledge is obtained, especially by means of on-site visual inspections. Municipalities are also responsible for traffic arrangements, evacuation orders, citizen requests for temporary residence and damage compensation. Although the responsibilities are well described in official plans, the experience confirms important delays in the supply of critical information for local emergency managers and the affected population as well as misinterpretations regarding responsibilities. The recent Mw5.2 Athens in 19 July 2019 revealed important confusion on issues such as which public body (EPPO or the municipalities) is responsible for receiving requests for the emergency assessment of building safety (semi-structured interview with EPPO officer).

The structure described above evidences fragmentation of responsibilities for the dissemination of emergency information and guidance in both the horizontal and vertical senses. This condition puts in question coherence and consistency of information and guidance.

3.1.2. Geoscience Information Centers

Long-term monitoring of seismic activity in Greece is being realized by the Hellenic United Seismic Network (HUSN) (For more details and map station, visit http://www.gein.noa.gr/en/networks/husn, accessed on 1 February 2021), unifying the seismological networks of four Greek institutes and universities. The Institute of Geodynamics of the National Observatory of Athens (NOAGI) is the leading earthquake analysis and monitoring center in Greece, monitoring the HUSN, the strong motion network, the global positioning system (GPS) stations network, the tsunameters network and the seismological portable network, continuously operating at all times with complete shift staff. Under NOAGI's coordination, the information regarding the on-going seismic activity is disseminated in the form of common announcements for events with a local magnitude over 4.0 (on the Richter/local magnitude scale). NOAGI's automatic system determines the rapid earthquake parameters (location, magnitude and depth) within about three–four minutes from the earthquake's origin time. This information is automatically published in NOAGI's website to inform the authorities and the public. The rapid earthquake parameters are also sent to the GSCP's Operations Center by automatically generated email and SMS messages.

Measurements of the earthquake size are subject to inherent epistemic uncertainty and gathering of more data allows more accurate measurements that are delivered from trained seismologists within 8–15 min. NOAGI's webpage is then updated, and management authorities (predominantly GSCP and EPPO) are informed by email, SMS and fax with the revised data. The public can obtain earthquake information by calling the NOAGI

operations center and listening to a recorded audio message, by talking directly to a duty officer or even by visiting the website updated with the latest earthquake alert. Uncertainty regarding the exact scale of a strong earthquake drops to the minimum when the moment magnitude (Mw) is determined. However, this achieved in no less than 15 min after the earthquake's occurrence and requires manual processing. The solutions are published in NOAGI's website and also supplied to the European Mediterranean Seismological Centre (EMSC).

The development of technology has offered immediate access to seismic information. The public has access to the rapid/initial earthquake information through cell phone applications (e.g., LastQuake of EMSC (LastQuake official webpage https://m.emsc.eu/, accessed on 5 April 2021). Such internet applications notify people in near real time when an earthquake hits a region of interest. Announcements also contain data related to the possibility of aftershocks (expected numbers of aftershock events, magnitude range and duration of the aftershock activity). This kind of information reflects high uncertainty due to its probabilistic content. There is no official operational framework of forecasting (e.g., a statistical model of aftershock rates) established in Greece, let alone the communication of forecasts to the public.

Finally, NOAGI provides automatic ShakeMaps of the estimated distribution of macroseismic intensities. At a later stage, these maps are enriched by EPPO-ITSAK with real time data. These maps are available in the official webpage of the Hellenic Strong Motion Network webpage (For details visit https://accelnet.gein.noa.gr/, accessed on 1 February 2021). These maps are characterized by aleatory variability and epistemic uncertainty.

The Hellenic National Tsunami Warning Center (HL-NTWC), supported by the tide gauge network, is the NOAGI's unit that is responsible for issuance of tsunami warning messages (TWMs) for Greece and the eastern Mediterranean Sea (For details visit http://hl-ntwc.gein.noa.gr/en/services.html#close, accessed on 15 April 2021). The threat level of the warning messages (released within about three minutes from the earthquake origin time, Figures 2 and 3) is based on rapid initial earthquake assessment (location, magnitude and depth), and the messages are usually issued and disseminated after earthquakes of $M \geq 5.5$ with epicenters offshore or close to coastal zones. Underestimation of the earthquake magnitude or epicenter inaccuracies may lead to a false alert level. TWMs are classified into three levels (information, advisory and watch) based on increasing wave severity (wave height and run-up) as well as possible effects on coasts. The TWMs are sent (by e-mail, fax and the Global Telecommunication System (GTS) simultaneously to the operation center of GSCP, the Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO), the Emergency Response Coordination Centre of the European Union (ERCC), the Joint Research Centre (JRC) and 17 agencies of 12 states subscribers (Analytical information can be found in HL-NTWC's official webpage http://hl-ntwc.gein.noa.gr/en/, accessed on 15 April 2021). An ongoing message is sent in the case of an observation of sea level change in the tide gauge records, providing information about the wave heights at a specific time and location, while the initial alert message is canceled when no sea level change is detected.

Focal Depth	Epicentre Location	Mw	Tsunami Generation Potential	Tsunami Message Type		
				Local	Regional	Basin-wide
<100Km	Offshore or close to the coast (≤40Km inland)	5.5≤ M ≤6.0	nil	information	information	information
		6.0< M ≤6.5	Weak potential for a destructive local tsunami (<100km)	Advisory	information	information
	Inland (>40Km and ≤100Km)	5.5≤ M ≤6.5	nil	information	information	information
	Offshore or close to the coast (≤100Km inland)	6.5< M ≤7.0	Potential for a destructive local tsunami (<100Km)	Watch	Advisory	information
		7.0< M ≤7.5	Potential for a destructive regional tsunami (≤400Km)	Watch	Watch	Advisory
		M >7.5	Potential for a destructive basin-wide tsunami (>400Km)	Watch	Watch	Watch
≥100Km	Offshore or inland ≤100Km	M ≥5.5	nil	information	information	information

Figure 2. Decision matrix regarding the type of tsunami message that should be formulated and disseminated for the Mediterranean basin as revised in March 2021. Source: HL-NTWC official website.

Message type	Tsunami Wave	Effects on the coast
Tsunami Watch	Tsunami wave height greater than 0.5m and/or tsunami run-up greater than 1m	Coastal inundation, potentially including all the phenomena described as potential coastal effects corresponding to tsunami advisory
Tsunami Advisory	Tsunami wave height less than 0.5m but larger than 0.2m and/ or tsunami run-up less than 1m	Currents, bore, recession, damage in harbours, small inundation on beaches
Information		No tsunami threat

Figure 3. Tsunami message type and respective tsunami wave severity obtained from the official webpage of the HL-NTWC.

Only recently (beginning in 2020) has GSCP disseminated TWMs to the public (see Section 4). Forecasting the characteristics of tsunami waves involves significant epistemic uncertainty related to not only earthquake rupture processes but also inundation or run-up processes that are strongly dependent on topographical effects, flow dynamics and land surface friction [22]. A significant component of ambiguity is also present in the response behavior of the population at risk (e.g., ignorance or underestimation of the risk by the local community; see Section 4.1).

Unquestionably, the existence of only one leading official agency reporting earthquake and tsunami scientific information is a merit of the emergency communication system in Greece, all the more so as it benefits from consensus and acceptance by most relevant university laboratories in the country. The initial-stage of TWMs is bedeviled by the possibility of failures of technology in the acquisition and elaboration of necessary data, i.e., an additional layer of uncertainty. During the subsequent stage of information supply on emergency operations and safety guidance, the information is bedeviled by higher uncertainty, inconsistency and delays.

3.1.3. Independent Announcements by Scientists

As mentioned in Section 2.3, uncertainty is interconnected with power and ethics; for instance, ethical issues arise regarding geoscientists' social and individual behavior [43].

Very often, before, during and after earthquakes, independent scientists and experts make statements via mass media (TV, radio etc.) and social media (e.g., posts on Facebook accounts), or their statements are uploaded on open-access scientific webpages. These statements may involve rapid information following an important earthquake event or guidelines regarding safety and assistance but also non-official earthquake predictions, aftershock forecasts, criticism towards or comments on official evaluations or response capacity. This often becomes a difficult problem to handle, especially when non-official statements regarding earthquake prediction are communicated to the public in a manner that breaches official regulations. The public usually trusts the recommendations of researchers and scientists more so than those of governments. This situation may evolve into a double crisis, i.e., a crisis of scientific controversy on top of a real seismic crisis [44], and result in an increase in public confusion, distrust, insecurity, distraction and panic.

3.1.4. The Role of Media and Social Networks

The most common source for the public to obtain information about an earthquake in Greece is the breaking news on TV and radio programs. Journalists relay the rapid

seismic information of the first minutes as determined by the geoscience institutions and organize on-site visits to the affected areas in order to collect and disseminate additional information about damages and victims. TV and radio also facilitate dissemination of instructions and advice issued by the management authorities. However, more often than not, seismologists' opinions contradict each other in the public and lead to uncertainty and perceptional confusion. An instructive example is the case of intense seismic activity in northwest Peloponnese (offshore of the town Amaliada) in February 2019. Five earthquake events with magnitudes of 4.2–4.7 were strongly felt, and, at the same time, a prediction of an upcoming event larger than 6.0 in western Greece was circulated through the media (Facebook). EPPO then was accused of a two-week delay in organizing a meeting to evaluate the prediction. Panic occurred among the local people, who slept outside their houses for days and weeks [45]. Power relations and antagonisms within and among the scientific community, media and politicians play a crucial role in public risk perceptions, in growing uncertainty and the generation of secondary, cognitive crises.

Nevertheless, social media, not only in Greece but worldwide, may contribute to first responders' and aid organizations' evaluations of the situation, issue warnings, provide instructions, identify survivors and victims and encourage volunteers and donations.

An online questionnaire survey conducted by the authors and addressed to university students and researchers–academics in Greece in March 2020 indicated that 70% of the participants prefer to use the internet (news websites) and social media in order to obtain information after the occurrence of earthquakes. In the same survey, GSCP was identified as the most trusted agency in terms of the provision of information regarding security during earthquake crises (66%).

The flowchart below (Figure 4) summarizes emergency information flow and the layers of uncertainty involved in each stage of communication.

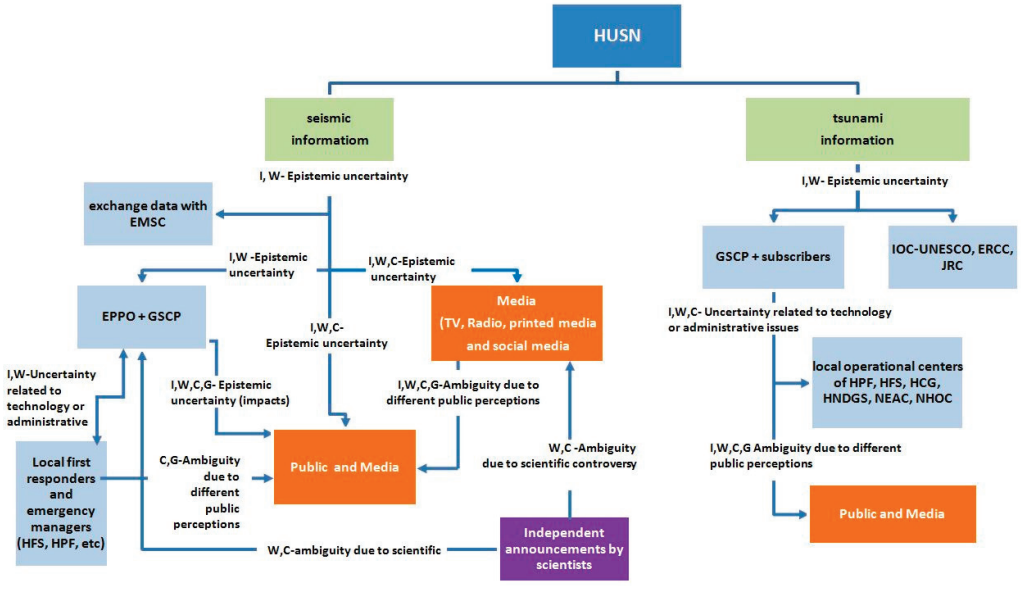


Figure 4. Flow chart of emergency seismic and tsunami information in Greece and the types of uncertainty involved in each phase of seismic crisis communication. Types of messages (see Section 1): I = Informative, W = Warning, C = Consulting, G = Guiding. Abbreviations of Organizations are explained in Abbreviations. Source: authors' elaboration.

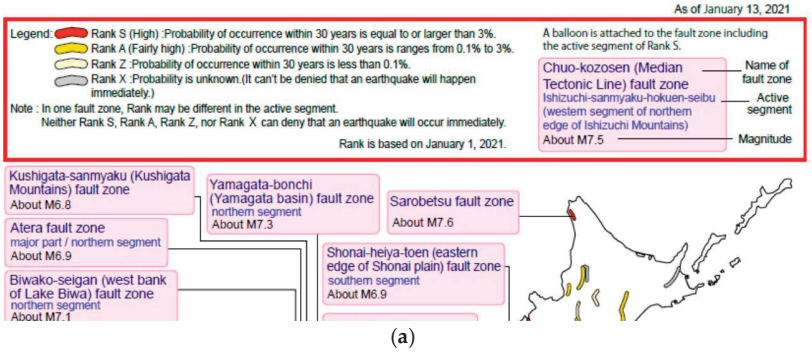
3.2. Japan

3.2.1. Geoscience Information Centers

Japan is one of the most seismically active regions in the world and is also located in a convergent plate boundary. The country has a rich experience in strong, devastating earthquakes, which are quite often associated with tsunami generation. After the 1995 earthquake disaster in Kobe, which killed 6434 people and destroyed over 100,000 buildings, the Special Measure Law on Earthquake Disaster Prevention was enacted to develop a robust policy on earthquake disaster prevention. The Headquarters for Earthquake Research Promotion (HERP) was then established, and it was directly attached to the Prime Minister's office with the aim of promoting earthquake research, clarifying responsibilities and providing the public and disaster prevention organizations with research findings.

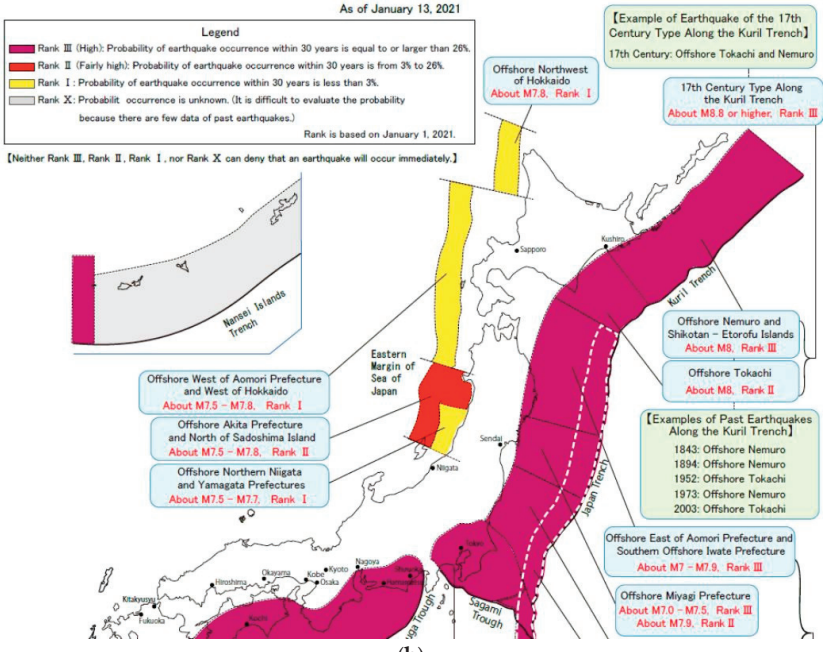
Once per month, HERP organizes meetings in order to evaluate seismic activity and publish relevant monthly reports on its official webpage. Supported by the Earthquake Research Committee of Japan (ERCJ) and the National Research Institute of Earth Science and Disaster Prevention (NIED), HERP publishes probabilistic seismic hazard maps (PSH maps). These maps illustrate the probabilities of occurrence and expected earthquake magnitudes evaluated on the basis of long-term occurrence probabilities for active faults on land and subduction zone earthquakes with a large social and economic impact (Figure 5a,b). Scenario earthquake shaking maps are also produced, illustrating ground motion intensity for specified source faults [46]. Both types of maps constitute the "National Seismic Hazard Maps for Japan" and are available to the general public and researchers on HERP's official webpage as well as the official page of the Japan Seismic Hazard Information Station (J-SHIS web portal).

The "National Seismic Hazard Maps for Japan" offer a fundamental contribution to the disaster management system, e.g., urban planning, building codes and even definition of countermeasures against large earthquakes in advance. The estimations illustrated in these maps influence the emergency seismic information, despite not being part of it. The input parameters of database scenarios and simulations used in warnings are strongly dependent on the estimations on these maps (see Section 4.2). It is well documented in the literature that PSH maps carry both types of uncertainty (Section 2.2): aleatoric uncertainty arising from variability in the source processes on a fault that changes from one earthquake to the next [47] and epistemic uncertainty associated with the evaluation of maximum magnitude and long-term occurrence rates [22].



(**a**)

Figure 5. *Cont.*



(**b**)

Figure 5. Part of the evaluation map of (**a**) major active faults (**b**) subduction zone earthquakes in Japan as of January 2021. Source: official HERP webpage.

The Japan Meteorological Agency (JMA), belonging to the Ministry of Land, Infrastructure, Transport and Tourism, is responsible for issuing earthquake information following an earthquake event and releasing early warnings (including tsunami warnings). JMA monitors a dense network of seismic intensity meters, seismometers, GPS stations, tide gauges and ocean bottom sensors around the clock. The earthquake information announcement involves the epicenter location, magnitude, seismic intensity parameters and possibility of tsunami occurrence. JMA issues a seismic intensity information report within two minutes, indicating the regions with a seismic intensity of three or greater; this is sent to the disaster management authorities via dedicated lines and reaches the public through local governments and the media in order to initiate emergency actions. This type of information is followed by the rapid information of basic focal parameters (hypocenter and magnitude).

In addition, JMA is responsible for issuing tsunami warnings/advisories and estimating tsunami height based on a developed tsunami forecasting system and a somewhat extensive tsunami propagation simulation database to support risk-sensitive urban planning and to provide a list of shelters and evacuation routes. JMA issues tsunami warning/advisory messages for the coastal regions of Japan within 2–3 min after the earthquake origin time. These messages provide information regarding the expected arrival times and heights of the waves based on computer simulations of tsunami waves. There are three category messages on the basis of the estimated tsunami heights (Figure 6). Since 2013, JMA has reduced the classes of tsunami heights from eight to five in consideration of uncertainty, estimation errors and impacts on disaster management [48] (Figures 6 and 7). The Tohoku Great East Japan earthquake on 11 March 2011 (Mw 9.0), the highest ever recorded in Japan, revealed the major problem of immediate determination of the exact magnitude of strong earthquakes (8.0 or over). Especially for these extreme cases (of large uncertainty), the content and expressions of the tsunami warning bulletins were revised: the "huge" and "high" qualitative expressions for the estimated maximum tsunami heights substituted

for the quantitative numerical expressions that were in place until then. Moreover, the initial tsunami warning is now based on the largest seismic fault expected in the area of the earthquake or on the predefined maximum magnitude to avoid underestimation. Updates of tsunami warnings are available within 15 min after the earthquake and are based on precise analysis of Mw calculations and tsunami observations.

Category	Indication	Estimated maximum tsunami heights		Expected damage and action to be taken
		Quantitative expression	Qualitative expression	
Major Tsunami Warning **	Tsunami height is expected to be greater than 3 meters.	over 10 m 10 m 5 m	Huge	Wooden structures are expected to be completely destroyed and/or washed away; anybody exposed will be caught in tsunami currents. **Evacuate from coastal or river areas immediately to safer places such as high ground or a tsunami evacuation building.**
Tsunami Warning	Tsunami height is expected to be up to 3 meters.	3 m	High	Tsunami waves will hit, causing damage to low-lying areas. Buildings will be flooded and anybody exposed will be caught in tsunami currents. **Evacuate from coastal or river areas immediately to safer places such as high ground or a tsunami evacuation building.**
Tsunami Advisory	Tsunami height is expected to be up to 1 meter.	1 m	N/A	Anybody exposed will be caught in strong tsunami currents in the sea. Fish farming facilities will be washed away and small vessels may capsize. **Get out of the water and leave coastal areas immediately.**

Figure 6. Categories of tsunami warning messages issued by JMA for coastal regions of Japan after the occurrence of strong tsunamigenic earthquakes. ** Major Tsunami Warnings are issued in the classification of Emergency Warnings. Source: official JMA webpage.

Warnings/advisories in effect	Observed heights	Information bulletin expressions
Major Tsunami Warning	Height > 1 m	Actual values
	Height ≦ 1 m	"Currently Observing" announcements
Tsunami Warning	Height ≧ 0.2 m	Actual values
	Height < 0.2 m	"Currently Observing" announcements
Tsunami Advisory	(all cases)	Actual values ("Slight" for very small waves)

Figure 7. Expressions used for observed maximum heights in coastal area. Source: official JMA webpage.

In the event of large earthquakes, JMA releases earthquake early warnings a few seconds before the strong tremors arrive (secondary waves), providing people with the opportunity to take protective actions and for important key transport means (trains and elevators) to slow down [49]. These warnings, despite containing uncertainty regarding the anticipated seismic intensity, are extremely valuable for the population and infrastructure networks. JMA relays these earthquake warnings through television and radio networks and cell broadcast networks. These multiple channels ensure reception of these early warnings by the entire population [50].

Special attention is given to the prediction of large-scale earthquakes with a magnitude of around 8 and a return period of every 100–150 years, referred to as "Tokai earthquakes", via the utilization of a seismic and crustal deformation observation network throughout the region (Figure 9). JMA is responsible for evaluating the possibility of a Tokai earthquake with the support of the Earthquake Assessment Committee (EAC). The warning declaration (earthquake prediction information) is released to the public by the Prime Minister. The Tokai Earthquake Warning is considered to have a double meaning: "alert", for a strong earthquake with a magnitude of 8 or higher, and "order", to be prepared and take necessary precautions.

As in the case of Greece, Japan has a knowledge intensive organization in place to release scientific emergency information, including both objective data regarding realized phenomena and probabilistic information regarding successive phenomena to follow.

As in Greece, this organization is also the initial/original producer of information in Japan and bears the responsibility to transfer it to central and local government management authorities, to the emergency mechanism and to the media. The difference between the two countries is that Japan's organization covers multiple hazards and is more closely connected to the emergency mechanism, since the deputy director general of JMA is a member of the emergency team. This tight and centralized structure facilitates easier communication of scientists with different forms of expertise in multi-hazard situations, as well as better collaboration between scientists, emergency managers and practitioners. Additionally, Japan's organization has more power, political acceptance and prestige due to its wide scope of knowledge and strong interconnection with the highest level of political decision making. Apart from the long-term operation of earthquake and tsunami early

warning systems in Japan, JMA's superiority in operating prediction of the next Tokai earthquake is unquestionable. However, predicting an earthquake is extremely difficult and after the Great East Japan earthquake, JMA acknowledged the possibility of magnitude underestimation of large earthquakes leading to erroneous estimations and warnings. This uncertainty has now been incorporated into the new warning message scale.

3.2.2. Public Administration Agencies as Emergency Information Sources and Management Authorities

The Central Disaster Management Council (CDMC), chaired by the Prime Minister and comprising all Cabinet members, heads of major public corporations and experts, is responsible for preparing and implementing the basic disaster management plan and earthquake disaster plans at the national level. In the event of a large-scale disaster, the Cabinet Office is engaged in collecting and disseminating accurate information, reporting to the Prime Minister, establishing the emergency system (including the Government's Disaster Management Headquarters) and overall coordination of the disaster response measures in the affected region.

The local disaster management plans are implemented by the Prefectural (Governor) and the municipal Disaster Management Councils (mayors). After receiving the earthquake information and tsunami warnings from the central government, the local authorities are able to release the emergency information to the local media and citizens within 4–20 s (in five languages) based on the J-alert system. J-alert is the satellite-based national early warning system used in Japan to directly release warnings on threats and emergencies to local media and the public (For more information, see https://www.centreforpublicimpact.org/case-study/disaster-technology-japan, accessed on 5 April 2021). Evacuation instructions and information on road conditions are also transmitted through this system. Updates of the emergency information are continuously provided. Additionally, the disaster emergency information is transmitted through loudspeakers and sirens to the public in coastal areas (in the case of a tsunami warning), while the warning messages appear on TV screens.

3.2.3. The Roles of Mass Media, Social Media and Social Networks as Information Sources

As was previously mentioned (Section 3.2.1.), as soon as an earthquake is detected and JMA issues an earthquake early warning, all of Japan's TV channels broadcast the alert message on their screens followed by instructions on how to react. This warning contains the estimated seismic intensities and expected arrival time of principal motion.

The use of social media during seismic crisis in Japan is extremely popular. In fact, JMA publishes a special report in order to familiarize the citizens with helpful Apps and Websites in the event of a disaster (Available online at http://www.bousai.go.jp/kokusai/web/img/02_bousai_guidebook_Web_EN.pdf, accessed on 15 May 2021). The smartphone application offers a wide range of information on earthquake parameters, tsunami warning and safety tips, shelters and assistance in the case of disaster. Media system dependency (MSD) theory states that "in an ambiguous situation, dependency on mass media increases because mass media outlets are likely to contain important and exclusive information that is not available from other sources" [51]. The author also states that dependency on media is intensified when people need to understand and act.

Japan has a robust, inter-sectoral and cohesive structure at the national level to deal with large-scale disaster emergencies. It is worth mentioning that the highest-level decision-making institution, the CDMC, consists not only of politicians and public administration officials but also scientists and experts, harmonizing political decisions with scientific information. Because of its composition and the trust that it enjoys, the CDMC does not leave much room for conflict or antagonism to be publicly presented.

The analysis of the crisis communication systems in Japan and Greece is summarized in Table 1 on the basis of the type of messages and message content.

Table 1. Important similarities and differences in crisis communication systems in Japan and Greece categorized by the type of messages and message content (in chronological order). Source: authors' elaboration.

Time of Issue	Types of Messages	Message Content	
		Japan	Greece
Prepared and published during the quiescence period	***Long-term Evaluation of the Seismic Activity*** Informative messages *Aleatory variability (source processes) and epistemic uncertainty (maximum magnitude and occurrences rates estimations).*	• ***National Seismic Hazard Maps for Japan:*** ***Probabilistic Seismic Hazard Maps (PSH maps) and Scenario Earthquake Shaking Maps (SESM)*** published every year.	• ***European Probabilistic Seismic Hazard Map:*** At a research stage • ***Seismic Hazard Zones*** (hazard is expressed in terms of Peak Ground Acceleration-PGA) and is produced for usage in the Greek Seismic Building Codes.
A few days before the possible event.	***Short-term earthquake forecast*** Warning messages *Probabilistic uncertainty with respect to the complex phenomenon but also related to the unpredictable behavioral reaction of the population and to inferences by the scientists.*	• ***Tokai earthquake prediction***	At a research stage
	***Earthquake Origin Time***		
Within a few minutes after the Earthquake Origin Time	***Rapid seismic-intensity information*** Informative message *Uncertainty related to the preliminary estimations of the parameters (depending on the magnitude estimation methodology and hypocenter location determination)*	• ***Earthquake Early Warning:*** epicenter and areas with expected seismic intensity ≥ 4. *Time:* within seconds in the case of large earthquakes. • ***Earthquake and Seismic Information:*** hypocenter, magnitude and seismic intensity. *Time:* automatic in 2–3 min, revised within 5–6 min. • ***ShakeMaps:*** estimated seismic intensity distribution, when seismic intensity ≥ 5, *Time:* several min.-hours after the earthquake, • ***Mw calculation*** *Time:* several min.-hours after the earthquake.	• ***Earthquake Early Warning***: at a research stage. • ***Earthquake Information***: magnitude, epicenter and depth. Time: automatic in 2 min., revised within 10–15 min. • ***ShakeMaps***: estimated seismic intensity distribution. Time: automatic in several min. after the earthquake, revised within min.-hours, • ***Mw calculation*** *Time:* several min.-hours after the earthquake.
	Tsunami Information Informative and Warning message *Epistemic uncertainty depending on first magnitude estimations and pre-simulated tsunami scenarios also related to technology or administrative issues. Uncertainty weakens when observed data are available.*	• ***Tsunami Warning:*** informing about the possibility of tsunami generation *Time:* Within 2–3 min, updated based on observations. • 3 levels of threat with expected wave heights. Qualitative approach: "huge" and "high" in the case of earthquake magnitude ≥ 8)	• ***Initial Tsunami Warning Message Informing about the possibility of tsunami generation***. *Time:* within 8–15 min, updated based on observations. • 3 levels of threat with numerical expressions of expected wave heights and effects on coasts.
Shortly after the earthquake (within the first hour) and continuously updated	***Safety measures*** Consulting messages *Uncertainty depending on level of preparedness*	Evacuation instructions (e.g., go to open areas or move to higher places)	
	Damage Assessment Informative messages *Epistemic uncertainty (lack of knowledge on the impact, reducible in time as* in situ *visits are realized)*	Injuries, buildings damaged, rescue operations if necessary.	
A few hours after the earthquake and continuously updated	***Guidelines*** Guiding messages *Uncertainty depending on level of preparedness*	assistance retrieval, refuge spaces, evacuation routes etc.	
Same day or a day after the earthquake and continuously updated.	***Assessment of Seismic Hazard and Evaluation of Seismic Risk*** Warning messages *Uncertainty related to probabilistic estimations and also due to inferences by the scientists.*	• ***"Aftershock Outlook"***: Probability of aftershocks	• ***Aftershock forecast***

Table 1. *Cont.*

Time of Issue	Types of Messages	Message Content	
		Japan	Greece
Means of dissemination of Seismic Emergency Information vs. Accessibility to the public			
	Uncertainty due to the Communication system characteristics. Ambiguity depending on level of preparedness and public risk perceptions	• Traditional media (TV, Radio, fixed-line telephone) • Official Websites of Organizations- Agencies Popular News Websites • Social Media and Smartphone Applications • Loudspeakers and sirens.	• Traditional media (TV, Radio, fixed line telephone) • Official Websites of Organizations- Agencies Popular News Websites • Social Media and Smartphone Applications

4. Examples of Actual Experiences of Seismic Crisis Communication and Impacts in Greece and Japan

4.1. Case studies in Greece

It is of great interest to analyze the tsunami early warning practices in Greece by examining recent actual experiences of tsunami crisis communication and management. All of the events mentioned in this section were associated with non-devastating tsunami waves. Nevertheless, these experiences represent important indications of the tsunami alert efficiency in Greece and the eastern Mediterranean Sea.

On 20 July 2017, Kos Island at the Greek–Turkish border in the Mediterranean Sea (Figure 8) experienced a strong earthquake of Mw 6.6 [52] that caused 2 casualties and hundreds of injuries due to building collapses [53]. A small-scale tsunami wave of up to 1.5 m arose 13 min after the earthquake at the island's port; this reached a height of 1.9 m when it arrived at Bodrum's peninsula in Turkey. The event was of limited magnitude, yet it raised intense concern regarding preparedness at the local, regional and national levels, as it revealed a lack of efficiency of tsunami warning practices in Greece. The initial earthquake information, as well as the tsunami warning (WATCH level) for the Mediterranean region, was released on time, and disaster prevention authorities were mobilized promptly. The tsunami alert was sent to GSCP (by fax) but unfortunately not received (or at least elaborated in time) by the local civil protection services (police, fire service, coastguard etc.). Consequently, the warning message never reached the local people on the island.

Emergency communication in Kos regarding the seismic event positively influenced people's behavior (remaining in open areas, sleeping outdoor etc.). However, this was not the case regarding the tsunami-associated risk. Before the earthquake, people considered a tsunami wave to be a "very large sea wave" [54], thus failing to realize that the port was hit by a tsunami and not by a storm wave. This is obvious, since people remained close to the coast after the earthquake-related shaking. In a totally missing preparedness context and with no recent memory of devastating tsunamis, the public's knowledge of tsunamis is based on other countries' experiences depicted in the media. The high touristic period might have also caused reluctance towards acknowledging the rise of the sea water as a threatening tsunami event. Only afterwards (several hours after the event) when the authorities disseminated informative videos of the tsunami did the majority of the local people become aware of what a tsunami wave is and how it can affect coastlines. After this failure, a local earthquake and tsunami warning system was established in Kos Island and Bodrum through the "Last Mile" collaborative project by NOAGI and JRC/EC supported by DG-ECHO/EC.

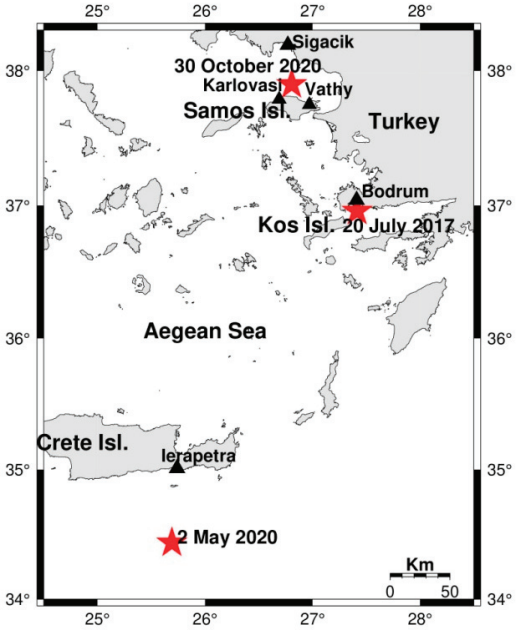


Figure 8. Map illustrating the epicenters (red stars) of the three earthquakes mentioned in Section 4.1. Source: authors' elaboration.

On 2 May 2020, a Mw 6.6 earthquake occurred in Crete (Figure 8); it was associated with a small tsunami of 16 cm recorded at Ierapetra tide gauge station 25 min after the earthquake origin time. The automatically calculated earthquake parameters led to false predictions about the tsunami wave height and effects on the coast. As soon as revisions were realized, the warning was upgraded [55], and the travel times of the tsunami wave were moved forward. Moreover, the public did not receive a tsunami alert, thus avoiding confusion by the change in the threat level alert. This change though caused confusion to the management authorities (GSCP).

Quite recently, on 30 October 2020 a strong earthquake of Mw 7.0 [56] struck the northern part of the island of Samos, Dodecanese, Greece and Izmir province in western Turkey (Figure 8). More than 115 people died due to building collapses (most of them in Izmir) and 1 person was drowned because of the tsunami in Turkey. Soon after the earthquake (15–20 min), a tsunami was generated, causing material damage to Karlovasi town (1.7 m high reaching the coast in about 10 min) and Vathy port (around 2 m). In Turkey, Sigacik bay was mostly affected, with one person killed by the wave (1.9 m height). Preliminary earthquake information was released immediately to GSCP (3–4 min), and within 10 min, the HL-NTWC had issued a tsunami warning message to government agencies. Due to the lack of tide gauges close to the earthquake's epicenter, water inundations along the coasts of Samos and Sigacik were reported by eyewitness observations and were released to the media before any recording of sea level change. The first recorded observations came from tide gauges more than 110 km from the epicenter. Nevertheless, GSCP was able to warn the public about a possible tsunami threat at the coastal zones in time before the second tsunami wave approached the coast [57]. This warning was disseminated through the European Emergency Number Service (112) (text message by SMS service) in both the Greek and English languages and was received on time. The response capacity of the National Civil Protection authorities in Greece has been improved, but shortening the alerting time still remains a challenge, considering the extremely short arrival times of the tsunami waves. Nevertheless, tsunami awareness of the local emergency officers

(police and port departments) appeared to have improved since orders for port evacuation and relocation to higher ground were in place almost a few minutes after the earthquake, leading to zero casualties in Greece.

To summarize, the lack of (accurate) information characterizing the near real time of earthquake–tsunami crises and the strong dependence of the initial alert levels on the preliminary uncertain seismic information pose significant difficulties in crisis management. The fundamental role of an enhanced sea-level observation network is also highlighted in terms of accurate and on-time measurements. However, a prompt warning (even if it is absolutely accurate) that fails to reach the population at risk contributes little to crisis management. On top of these layers of uncertainty, a low tsunami risk perception of people in Greece represents an additional layer.

4.2. Case Study in Japan

On 11 March 2011, a devastating earthquake with a magnitude of Mw 9.0, known as the Great East Japan Earthquake, occurred in Tohoku, Japan, Pacific Coast (Figure 9). It is the largest earthquake ever recorded in Japan, and it is among the five largest recorded worldwide.

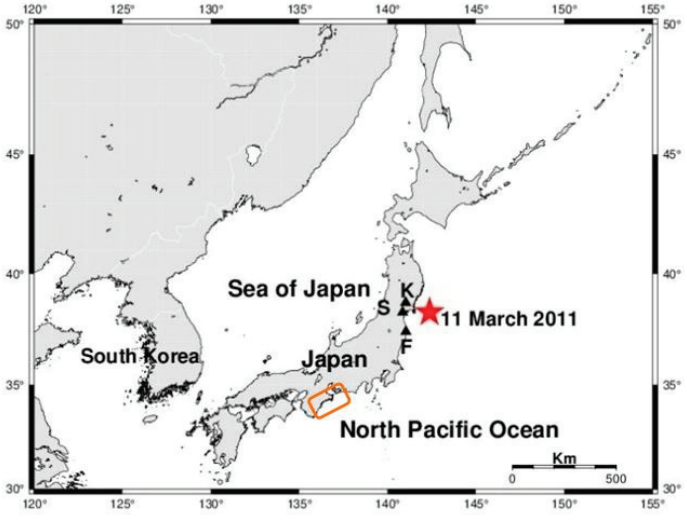


Figure 9. Map illustrating the epicenter (red star) of the Great East Japan Earthquake, 11 March 2011. K = Kurihara city, S = Sendai and F = Fukushima. Source: authors' elaboration. The orange rectangle illustrates the hypocentral region of Tokai earthquakes.

Japan is a tsunami-resilient community featured by high preparedness levels reflected in the advanced forecasting and communication technology, well considered urban planning, structural and non-structural countermeasures against tsunamis and an engaged population well trained for tsunami disasters. However, the country mourned over 18,000 victims after the Great East Japan Earthquake and over 4000 missing individuals [58]. The tsunami run-up height reached up to 40 m in Iwate prefecture [59] and a tsunami 14 m high caused an explosion at Fukushima nuclear power plant I [60], resulting in extensive radioactive contamination. In Sendai region, the tsunami penetrated land along a zone with a width of about 5 km. Japan was criticized for making "methodological mistakes" [61] referring to hazard analysis and poor safety measures against tsunamis in the nuclear power plant zone. The authors of [59] argue that such a huge tsunami should not be considered a surprise, as past earthquakes of a smaller magnitude produced similar waves, revealing the impact of local topography.

The initial magnitude estimation was 7.9 MJMA, and three minutes after the earthquake, JMA, based on this underestimated value, issued an initial tsunami warning with an underestimated forecast of tsunami heights: 6 m in Miyagi prefecture and 3 m in the coastal areas in the prefectures of Iwate and Fukushima located less than 100 km from the earthquake's epicenter [48]. It is worth mentioning that JMA considered the initially calculated value of the magnitude (7.9 MJMA) as being reliable, since an earthquake of this order was expected in the region. Many people did not try to evacuate since they felt safe behind a 10 m seawall [60], losing precious time with fateful consequences. As soon as the tsunami wave was observed at offshore tsunami buoys (28 min after the earthquake) and the source parameters were updated, JMA revised the estimation and updated tsunami warnings: over 10 m for Miyagi Prefecture and up to 6 m for the prefectures of Iwate and Fukushima.

Another important issue was electricity failure in several communities where the radio and/or public speaker system did not work due to blackouts. Consequently, the earthquake announcement and advice to move to higher places were not communicated. This failure led to later enhancing the observation facilities by installing an emergency power supply and developing a satellite-based emergency communication system as a backup in case of damage to the terrestrial facilities.

The need for information in the case of the 11 March 2011 seismic and tsunami crisis was also reflected in the use of social media. There is a great number of relevant publications [62,63], particularly in relation to Twitter [64–67], referring to the usage and contribution of social media to disaster mitigation. The earthquake caused ambiguity in the social environment. Research by [68] showed that Facebook, Mixi and Twitter were mostly used for users to gain information about the event (confirming MSD theory) and safety of friends. Smart phones became the main communication device.

The case of Greece suggests that the most critical types of uncertainty originate from low levels of awareness of the public and diverse knowledge frames of emergency managers. In the case of Japan, failures derive from the accurate and specialized content of warnings based on uncertain information, thus distorting public risk perceptions and the protective measures undertaken or not undertaken.

5. Discussion

The authors of this paper have attempted to present the existing standards and norms of formal and informal emergency information dissemination processes in post-earthquake crises with special emphasis put on the uncertainty issue. The fundamental objective has been to trace the impact of uncertainty on crisis management and suggest tips for crisis communication strategies in earthquake-prone countries. It was observed that uncertainty in seismic crisis communication is associated with the following: (a) lack of knowledge and data, especially within the first few minutes following the event; (b) inherent variability present in the seismic phenomenon; (c) ambiguity originating from contradictions between expert knowledge frames and different public perceptions; (d) technological gaps and failures; and (e) coordination and governance barriers.

In chronological order, the messages released to the public in seismic emergency periods are informative (reporting earthquake magnitude and epicenter, injuries, damages etc.), warning (notifying of secondary effects and tsunamis or forecasting of aftershocks), consulting and guiding (including recommendations and instructions on safety measures and protective actions). Each subsequent message group builds on the previous one and several uncertainty layers are added gradually from the informative messages through to the instructive. In the most advanced crisis communication systems (Japan), the informative and warning messages of the first minutes are based even on pre-earthquake research data and parameters, in particular the Hazard Maps and the Scenario Earthquake Shaking Maps (updated on a yearly basis).

In the course of time of the emergency period prognostic information is substituted gradually by observations and real-time data; as a result, uncertainty gives ground to

certainty and consulting and instructive messages are updated and enhanced. While the high uncertainty messages of the first minutes are far from accurate and reliable, they are still very useful under conditions of emergency when rapid responsive actions are indispensable. This has been demonstrated by the Japanese system, which takes advantage of even the few seconds before the strong tremors arrive to release warnings in order to activate protective responses of people and the operators of infrastructure networks.

Uncertainty is also associated with the sources of emergency messages: Scientific institutions and central government management authorities in close cooperation with each other are liable basically to epistemic uncertainty; regional and local management authorities are subject to additional uncertainties arising from coordination and governance failures as well as technological deficiencies; mass and social media as well as independent expert announcements carry uncertainty that is created by diverse risk perceptions and conceptions, power relations and antagonisms.

The content of the emergency messages may either disregard or take uncertainty into account. A good example of the first case is the TWMs in Japan before 11 March 2011 (the date of the Tohoku Great East Japan earthquake) expressed then in accurate numerical values and resulting in the dramatic consequences of the disaster of 2011. A good example of the second case is the Japan's revised classification of TWMs after the 2011 disaster where the quantitative terms were substituted by qualitative to prevent creation of false perceptions. However the information that is overly generalized and vague does not raise awareness.

6. Conclusions and Recommendations

The important research query that the authors have raised from the beginning of the present work refers to the impact of uncertainty on crisis dynamics and disaster management. The major relevant findings are presented below:

i. Epistemic uncertainty and variability inherent to the phenomenon are present in every case of seismic-prone country and influences the management actions and the level of trust toward the sources of information. It is evident that the emergency information of the first minutes after the initial seismic shock should be produced and disseminated as "transitional" information, thereby allowing it to be updated and for further details to be provided later. The communities that are affected by such crises should be trained to expect and live with the intermediary, insufficient and imprecise content of the first round of messages. Management authorities, on the other hand, should follow the precautionary principle at this early crisis stage and issue only short-term but maximum protection instructions.

ii. Ambiguity and cognitive diversity influences behavioral actions and adaptation/protection measures. Diverging cognitive frameworks create mistrust, cognitive disorder and chaos in the affected community. In general terms, cooperation/unification of the several scientific agencies and viewpoints and their alignment with political decision-making represent a good strategy that does not leave much room for disagreements in periods of emergency. In the case of Greece, the connections of the scientific agencies with the political/administrative hierarchy have remained weak, and the political and scientific antagonisms not only hamper crisis management but may cause the generation of secondary crises. In contrast to the case of Greece, Japan is featured by strong connections between the scientific institutes and the political/administrative structure at the highest level of the political hierarchy (the Cabinet's Office), enhancing the trustworthiness of both scientific guidance and political decision-making. However, this tight and rigid structure at the national level may create difficulties in coordination with and embeddedness of the local level into the emergency information exchange and decision-making system.

iii. Uncertainty due to governance and coordination problems has important detrimental effects on prompt warning and response time. Japan represents a coherent administrative structure with well-trained members to address effectively large-scale disaster

emergencies. On the other hand, in Greece, low coordination capacity was observed in the case of the Kos seismic crisis: the processing of emergency messages from the centrally located HL-NTWC to the distant island of Kos was delayed. In a totally missing preparedness context, the tsunami risk perceptions of the local people were shaped exclusively by past media reports referring to only huge tsunamis with devastating results. Therefore, the local community did not even have the opportunity to recognize the potentially dangerous local phenomenon.

iv. Technological gaps are present in all seismic-prone countries and influence information circulation and accessibility. Power outages and heavy traffic in official webpages are common problems during a seismic crisis. When the transmission of the emergency messages is interrupted, disaster preparedness and awareness are essential to save lives.

Both experiences in Greece and Japan clearly indicate the merits but also the weaknesses of the highly centralized emergency communication systems. On the one hand, they are beneficial in terms of wide public acceptance, confidence and legitimacy, but, on the other hand, they are disadvantageous in that they allow only limited feedback from the local level empirical data, biophysical risks [69] and local risk perceptions and cultures.

After the aforementioned discussion and conclusions, the following recommendations seem to be critical for seismic crisis communication strategies to reduce uncertainty:

- Promote research in seismology to reduce epistemic uncertainty;
- Provide for alternative means of communication (resilience) to reduce uncertainty from technological failures;
- Upgrade preparedness level and organize training courses for the population, first responders and managers on the standardized emergency communication procedures to avoid misconceptions of messages and false perceptions during the crisis;
- Ensure a commonly shared minimum risk knowledge level among emergency managers;
- Immediately after the earthquake origin, issue only short-term but maximum protection consulting and instructive messages (apply the precautionary principle);
- Take care to constantly update the first, highly uncertain emergency messages and give advice to the population to constantly search for refreshed information;
- Connect recent pre-disaster research findings (hazard and shake maps) with the informative and warning messages of the first minutes after the earthquake origin;
- Do not cover up uncertainty in the emergency messages;
- Do not issue warning messages that are very specific/accurate (hiding uncertainty) or very general (i.e., ineffective in triggering protective responses);
- Build a unique, unified and unanimous scientific-crisis management structure at central/national level but ensure constant exchange of information and feedback from and to the regional and local level as well as independent experts. Multi-hazard and multi-risk observatories at the regional/local level could contribute to this direction by performing the following functions: (a) receive centrally processed scientific information and data and respond with feedback information on the basis of local observations; (b) make local observations of primary and secondary hazards and systemic risk dynamics with the support of new technologies; and (c) operate two-way emergency information communication with the exposed regional/local communities.

It should be expected that this combination of top-down and bottom-up styles of emergency communication will reduce uncertainty.

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Abbreviations

CDMC	Central Disaster Management Council
J-SHIS	Japan Seismic Hazard Information System
EAC	Earthquake Assessment Committee
MSD Theory	Media System Dependency Theory
EMSC	European Mediterranean Seismological Centre
NEAC	National Emergency Aid Centre
EPPO	Earthquake Planning and Protection Organization
NHOC	National Health Operations Center
ERCC	Emergency Response Coordination Centre of the European Union
NIED	National Research Institute of Erath Science an Disaster Prevention
ERCJ	Earthquake Research Committee in Japan
NOAGI	Institute of Geodynamics, National Observatory of Athens
ETAS model	Epidemic-Type Aftershock Sequence
GPS	Global Positioning System
OBS	Ocean Bottom Sensors
GSCP	General Secretariat for Civil Protection
PSH maps	Probabilistic Seismic Hazard maps
GTS	Global Tele-communication System
PSHA	Probabilistic Seismic Hazard Assessment
HCG	Hellenic Coast Guard
PSSC	Permanent Special Scientific Committee for the Assessment of Seismic Hazard and the Evaluation of Seismic Risk
HERP	Headquarters for Earthquake Research Promotion
HFS	Hellenic Fire Service
HL-NTWC	Hellenic National Tsunami Warning Center
PTHA	Probabilistic Tsunami Hazard Assessment
HNDS	Hellenic National Defence General Staff
PTWC	Pacific Tsunami Warning Center
HPF	Hellenic Police Force
SHA	Seismic Hazard Assessment
HUSN	Hellenic United Seismic Network
TEW	Tsunami Early Warning
IOC-UNESCO	Intergovernmental Oceanographic Commission of UNESCO
TWM	Tsunami Warning Messages
ITSAK	Institute of Engineering Seismology and Earthquake Engineering
JMA	Japan Meteorological Agency
JRC	Joint Research Centre

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A Comprehensive Assessment of Exposure and Vulnerabilities in Multi-Hazard Urban Environments: A Key Tool for Risk-Informed Planning Strategies

Adriana Galderisi and Giada Limongi *

Department of Architecture and Industrial Design, University of Campania "Luigi Vanvitelli", 81100 Caserta, Italy; adriana.galderisi@unicampania.it
* Correspondence: giada.limongi@unicampania.it

Abstract: Although the increase in the frequency and intensity of disasters assigns a key role to disaster risk management in current debate on sustainable development, the efforts of national and local authorities to develop risk-informed planning strategies and increase disaster preparedness are still limited. In multi-hazard urban environments, the main criticality to support risk-informed planning strategies is the persisting lack of effective knowledge bases focused on the vulnerability of exposed assets to different hazards. Hence, this contribution, according to the first priority of the Sendai Framework for Disaster Risk Reduction—understanding disaster risk—and by tidying up methods and indicators developed in both EU research projects and scientific studies devoted to multi-risk and vulnerability assessment, aims at better using available knowledge to guide risk-informed spatial planning. In detail, an indicator-based method to carry out a comprehensive exposure and vulnerability analysis has been outlined and tested on a case study area, the multi-hazard urban area of Campi Flegrei, located in the western part of the metropolitan city of Naples in the South of Italy. The proposed method may contribute to the building up of an effective risk knowledge base, enabling planners to easily access information on exposure and vulnerabilities to different hazards, and to differently combine them into output maps capable of supporting risk- informed planning strategies.

Keywords: exposure; vulnerability; systemic vulnerability; risk-sensitive spatial development; multi-risk

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1. Introduction

Despite the emphasis put on disaster risk reduction (DRR) and climate change adaptation (CCA) in all recent documents on sustainable development, urban areas are still prone to the frequent impacts of individual or coupled hazards. Moreover, the constant growth of urban population and the increasing interconnectedness among urban elements and systems result in a growth of their exposure and vulnerability levels. Hence, it is urgent to develop risk reduction strategies, based on a multi-risk assessment capable of taking into account the different hazards potentially affecting a given area and their likely interactions, as well as the different assets exposed to each hazard and their multiple vulnerabilities.

The importance of a better understanding of disaster risk has been also remarked by the Sendai Framework 2015–2030 that assigned to risk knowledge a fundamental role to support all the phases of the disaster cycle. The document clearly outlines the key steps to improve risk knowledge, putting emphasis on the importance of consolidating the existing knowledge, of considering all risk components (hazard, exposure and vulnerabilities) and their potential interactions, of encouraging the use and strengthening of baselines at relevant spatial scales and their periodical updating as well as of ensuring an effective dissemination of such knowledge to different stakeholders. Moreover, the Sendai Framework underlines the importance of promoting comprehensive multi-risk analyses by taking into account climate change scenarios.

However, even though over the past few decades, the relevance of multi-risk analyses has been largely recognized, this issue is still mostly confined to scientific debate, while current practices are often based on consolidated methods and procedures for single hazard/risk analyses [1–4].

The shift from risk to multi-risk assessment requires a radical change in perspective. While risk analysis has been for long "hazard-centered", starting from the characterization of individual hazards and their spatial distribution that leads to the identification of the potentially affected areas and elements at risk, multi-risk analysis should be "spatial-centered", starting from the selection of a geographical area in order to identify, firstly, the multiple hazards it is prone to and their potential interactions, and secondly, the exposed and vulnerable elements both to single hazards as well as to chained or coupled ones [5–8].

Comprehensive multi-risk analyses are paramount to support effective disaster risk reduction policies in existing urban areas, generally characterized as multi-hazard environments, with high levels of exposure and vulnerability, due to the constant growth of urban population and the increasing concentration of activities and assets. In these areas, risk-informed planning strategies, by acting on exposure and vulnerability features of urban areas to different hazards, could largely contribute to reduce current multi-risk levels, which are generally higher than risk levels measured in respect to individual hazards [5,6].

Nevertheless, even though the pivotal role of spatial planning for effective disaster risk reduction policies has been largely emphasized by numerous scholars and international documents on DRR, existing knowledge is often inadequate to support risk-informed planning strategies, which require detailed information on the vulnerabilities of exposed assets and systems [3,9,10].

Based on these premises, this contribution is addressed to outline a methodological path to carry out a comprehensive exposure and vulnerability assessment in urban areas prone to multiple hazards as a first step towards a multi-risk analysis and aimed at supporting risk-informed planning strategies. In detail, Section 2 highlights the main gaps in currently available risk knowledge as well as the main outcomes of research works focused on multi-risk assessment; Section 3 outlines the key steps of the proposed methodological path; Section 4 provides an application of the methodological path on a multi-hazard urban environment, the Phlegraen Fields in the metropolitan area of Naples (Southern Italy); and Section 5 emphasizes the relevance of the proposed methodology for planning issues. The last Section 6 discusses the obtained results and offers some concluding remarks.

2. Risk Knowledge: Current Gaps and Advances

Despite the recognized importance of comprehensive multi-risk analyses to support effective DRR and CCA strategies, risk knowledge currently available still shows several shortcomings: fragmented knowledge bases developed by different authorities in charge of individual hazards; heterogeneous terminologies and methodologies for hazard and risk analysis; data and information provided at different geographical scales and not always up-to-date; frequent lack of in-depth vulnerability analyses as well as of adequate platforms to collect, synthesize and share existing data and information [11]. All these shortcomings hinder the possibility to effectively support risk-informed planning strategies: as the latter act on different spatial scales and according to different aims, they require both aggregate indexes to select the areas characterized by the highest multi-risk levels and disaggregate and detailed information on exposure and vulnerability at different scales to define adequate DRR strategies.

However, in the past decade, significant progress towards the development of comprehensive multi-risk analyses has been achieved, even if the increase in knowledge is not matched by its greater use in practice [12].

The topic of multi-risk analysis has been addressed by numerous scholars and European research projects, although according to different perspectives (e.g., na-tech events, simultaneous or cascading events, vulnerability to multi-hazard) [13,14], and several review articles highlight the relevance of multi-risk in scientific literature and the different methods

so far developed to improve risk knowledge in multi-hazard environments [3,4,6,13–15]. Most of the available methods can be traced back to two large groups: scenario techniques and indicator-based methods.

Some studies traceable to the first group have developed complex risk scenarios, based on site-specific hazard data and focused on selected chain of events and elements-at-risk [16,17]: they clearly highlight how the interactions among different hazards may amplify the overall risk level in respect to the levels due to individual hazards. However, although very relevant to understand the complexity of chained events and urban systems as well as to define comprehensive risk indexes, they do not provide disaggregate data and information on the different risk components (exposure and vulnerability) useful to better guide risk-informed planning strategies.

Studies traceable to the second group have developed numerous sets of indicators aimed at providing a picture of the different risk components [18–21]. According to indicator-based methods, for instance, Kappes et al. [19], carried out a vulnerability assessment in multi-hazard contexts; Gallina et al. [22] developed a multi-vulnerability matrix, taking into account the physical and environmental vulnerability of different exposed targets prone to multiple climate-related hazards. However, these studies often fail in providing a comprehensive multi-risk assessment: focusing on specific "facets" of vulnerability; in fact, they generally overlook its multidimensional feature [23].

Nevertheless, indicator-based methods seem to be the most adequate to support risk-sensitive planning strategies [20,24]: they allow providing, without requiring massive data collection and elaboration or specific technical skills [22], both summary results and disaggregate information on individual risk components that are crucial, in turn, to support planning choices.

Therefore, with reference to an indicator-based method, this contribution aims at providing a methodological path to carry out a comprehensive analysis of exposure and vulnerability in urban areas prone to multiple hazards. In detail, the proposed path takes into account the multiple "facets" of vulnerability (physical, social, systemic) and allows building up a set of "spatialized" data and information, collected through open datasets, that can be combined into different output maps: from thematic maps, showing the vulnerability features of selected elements (e.g., residential buildings), to a comprehensive map, showing the overall levels of exposure and vulnerability of a given area in the face of multiple hazards. Thus, it provides a screening tool useful to prioritize the most vulnerable exposed areas and assets, but also to identify effective strategies to reduce their exposure and vulnerability levels.

3. The Methodological Path

As mentioned above, multi-risk analyses must be tailored to the context; thus, in this section, the main steps of the methodological path will be roughly presented to be then further detailed in respect to the selected case study (Section 4).

In order to carry out a comprehensive analysis of exposure and vulnerability of a selected area, two preliminary steps are required. First of all, available information related to the different hazards that the selected area is prone to have to be collected and codified. Secondly, the selected area has to be divided into homogeneous spatial units (HSUs), obtained through the overlapping into a GIS environment of three basic layers: minimum census units, as defined by the national census bureau, land uses (as defined by the Corine Land Cover) and hazard distribution. HSUs allow a "spatialization" of different data and information that, collected in respect to HSUs, can be then easily aggregated at different geographical scales.

3.1. Exposure and Vulnerability Indicators

Exposure levels of an urban system or of its partitions depend on the presence and consistency of "target elements"; that is, the elements that can be potentially affected by the hazards that a given area is prone to. Hence, their identification depends on the type

of hazards affecting the selected area. Target elements can be articulated into two main categories: areal elements (e.g., residential areas, areas devoted to tertiary, commercial, tourist activities, etc.) and punctual elements (urban facilities, archaeological sites, industrial plants, etc.). These elements can be investigated through exposure indicators related to the distribution and density of areal elements or to the location and number of punctual elements.

Vulnerability has long been one of the most debated concepts in the field of DRR, and vulnerability analysis is nowadays considered crucial to both risk and multi-risk assessment: the development of effective disaster risk reduction strategies requires an in-depth knowledge of "who and what is most vulnerable" [25].

However, vulnerability is a multifaceted concept, referring to "the conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards" [26].

The diversity of the vulnerability facets is also mirrored by the heterogeneity of the available methods to analyze and assess it [27,28], which range from fragility curves, to qualitative and quantitative indicators [20,29].

Among the several dimensions of vulnerability arising from European research projects [23] as well as from the numerous scientific articles that over the years have addressed vulnerability issues [30–33], we will focus here on three facets:

- Physical, which is the most investigated facet together with the social one; it is widely interpreted as the susceptibility of a given element/asset to be damaged (buildings, infrastructure, forests, etc.) [27,34].
- Social, which is generally related to the capacity of individuals and communities to cope with the adverse impacts of hazards [32,35].
- Systemic, the less investigated facet, which is typical of complex urban systems, since it mirrors the propensity of territorial elements to suffer damage (generally a functional damage) due to their linkages with other elements [36,37]; hence, this vulnerability facet is mostly related to the type of linkages among territorial elements, rather than to the hazard typology. Examples of systemic vulnerability are the failure of an electrical network that may induce cascading effects on several productive activities, or the permanent or temporary blockage of a road that may impede the accessibility of an emergency facility.

Despite being the least investigated facet of vulnerability, the concept of systemic vulnerability has been applied in several areas of natural hazards such as earthquakes, floods and volcanic eruptions [37–40] and it is nowadays considered as crucial to a better understanding of the overall vulnerability of urban systems. As a matter of fact, urban facilities and infrastructure play a crucial role for the "functioning" of urban systems both in peacetime and, even more, in case of a hazardous event, when their "malfunctioning" could induce a significant increase in the loss of lives and properties. These elements are numerous and diversified, ranging from hospitals and schools, to road and rail networks. In respect to these elements, it is important to analyse, besides their physical vulnerability, their susceptibility to suffer a reduction or even a loss of functionality due to their linkages with other elements of the urban system. The loss of functionality of a given element may influence, in fact, the functioning of the whole urban system, determining its failure in providing adequate responses in the aftermath of a hazardous event.

The focus on the three vulnerability facets is closely related to the adopted spatial-planning perspective. These facets are crucial indeed to support planning strategies aimed at recovering/regenerating existing urban areas, whereas they also provide useful insights for emergency management. For instance, physical vulnerability is paramount to support retrofitting strategies, while social vulnerability indicators may be very useful to better drive regeneration strategies at neighborhood or municipal scale. Moreover, systemic vulnerability indicators, by identifying the main shortcomings of urban facilities, strategic equipment and/or infrastructure, can support strategic plans at a metropolitan or regional

scale towards the relocation of urban facilities or strategic equipment as well as towards the strengthening of the mobility networks.

Thus, the assessment of the vulnerabilities of exposed targets through qualitative-quantitative indicators allows:

- Characterizing some relevant aspects of exposed elements or systems through simple indicators or through their combinations into compound indicators;
- Replicating the analysis by adapting the set of indicators to different contexts and at different scales, by easily comparing different urban areas or territorial systems.

The set of vulnerability indicators can be outlined based on some European research projects and scientific articles (Table 1) that over the years have provided methods and tools to assess vulnerabilities both in a single-risk and in a multi-risk perspective.

Table 1. Main references for the selection of indicators.

EU Projects	**Vulnerability Facets**
ARMONIA 2004–2007	*physical v.* *social v.* *systemic v.*
ENSURE 2008–2011	*physical v.* *social v.* *systemic v.*
MOVE 2008–2011	*physical v.* *social v.* *systemic v.*
RESIN 2015–2018	*physical v.* *social v.* *systemic v.*
References	**Vulnerability facets**
Cutter et al., 2008	*social v.*
Barbat et al., 2010	*physical v.*
Kappes et al., 2012	*physical v.*
Tilio et al., 2012	*systemic v.*
Welle et al., 2013	*social v.*
Scaini et al., 2014	*systemic v.*
Aliabadi et al., 2015	*physical v.* *social v.* *systemic v.*
Khademi et al., 2015	*systemic v.*
Papathoma-Köhle et al., 2017	*physical v.*
Elboshy et al., 2019	*physical v.* *social v.* *systemic v.*

In detail, several indicators aimed at assessing physical vulnerability of built environment in the face of natural hazards [27,34,41,42] have been so far defined in the field of engineering studies; they generally refer to the structural features of buildings as well as to their maintenance (e.g., construction typologies, age of buildings, conservation degree) [43]. More recently, some indicators related to the physical vulnerability of the built environment to climate related hazards (e.g., floods, heat waves) have been also developed, such as the imperviousness of the urban fabrics' surfaces and the vegetation index [44].

Available indicators useful to characterize social vulnerability generally include population structure, such as the old-age index, the percentage of elderly and children compared

to the resident population, which allows defining a dependency ratio and the difficulty of autonomous travel in case of evacuations; the education rate and presence of social marginalization; and employment levels, which affect the capacity of individuals to cope with hazards' impacts [45].

Indicators related to systemic vulnerability generally refer to the type of available urban facilities and infrastructure, to their functional role/relevance in a given context as well as to their redundancy. In particular, available studies on systemic vulnerability often refer to the redundancy of territorial facilities, to the accessibility levels of the different areas/facilities as well as to the redundancy and connectivity of the transport networks [46,47].

3.2. From the Selection of Indicators to the Output Maps

Once the set of indicators has been selected, each indicator can be measured through data collected from different datasets. The raw data deriving from the available datasets have to be associated to the different HSUs and to the specific indicator, homogenized and normalized according to a common scale of values [10]. It is worth pointing out that while exposure, physical and social vulnerability indicators can be measured through a "soft" reprocessing of data extracted from existing databases (e.g., National Census, Copernicus layers), systemic vulnerability indicators require more in-depth analyses of features and functional roles of urban and emergency facilities as well as of road and railway networks, that, however, can be obtained thanks to GIS tools and do not require in situ surveys.

Then, as for hazards, all the selected exposure and vulnerability indicators require a coding process, in order to combine them into a comprehensive exposure and vulnerability assessment. Moreover, due to the heterogeneity of the collected data, all exposure and vulnerability indicators can be homogenized and normalized in a range from 0 to 1, according to the formulas:

$$e'_{x,y,z} = (e_{x,y,z} - e_{x,y,z,min})/(e_{x,y,z,max} - e_{x,y,z,min}) \quad (1)$$

$$v'_{x,y,w} = (v_{x,y,w} - v_{x,y,w,min})/(v_{x,y,w,max} - v_{x,y,w,min}) \quad (2)$$

where:

- $e_{x,y,z}$ is the not homogeneous exposure level of exposure indicator z attributed to the element y;
- $v_{x,y,w}$ is the not homogeneous vulnerability level of vulnerability indicator w attributed to the element y.

The main output of this process is represented by single homogenized maps where each HSU is related to values of e', v' ranging from 0 to 1. Then, in order to switch from a collection of maps related to each homogenized indicator to a comprehensive exposure and vulnerability map, the different indicators can be combined with each other. In detail, exposure and vulnerability values, calculated in respect to each hazard, can be combined to obtain a total exposure value multiplied by vulnerability values:

$$VE_x = \sum e'_{x,y,z} \left(v'_{x,y,1} + v'_{x,y,2} + \ldots + v\prime_{x,y,n}\right) \quad (3)$$

where the total value VE of a given area to the hazard (x) is given by the sum of each exposure indicator (z) multiplied by the sum of the vulnerability indicator values (n).

This step allows obtaining two main outputs:

- Single maps showing the distribution of exposure and vulnerability levels (EV Map), in respect to the hazard (x), for each class of exposed element;
- Single maps showing the distribution of exposure and vulnerability levels (EV Map) in respect to the hazard (x), with a scale normalized on the worst case (maximum value of $VE_{x,y}$) (Figure 1).

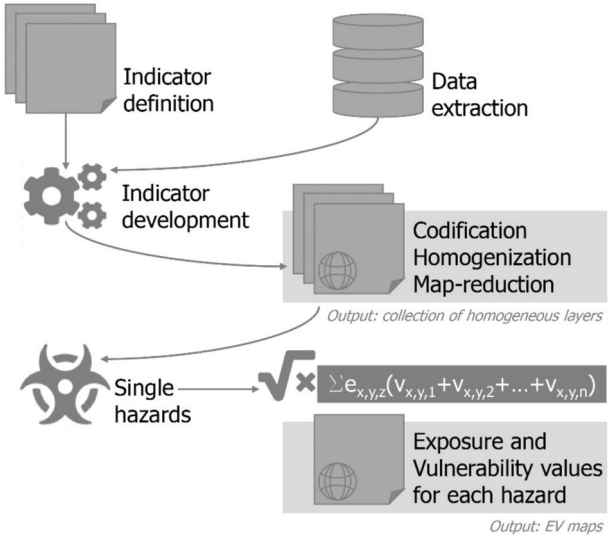

Figure 1. The process from data extraction to the output maps.

These maps can be obtained by multiplying exposure levels with the sum of vulnerability indicators' values attributed to each class of exposed elements, or by considering the total exposure value with its vulnerability value for each hazard following the Formula (3).

Finally, besides the EV maps related to each hazard, it is possible to carry out a comprehensive EV map, which provides a summary value of exposure and vulnerability levels of each HSU in respect to all hazards affecting the case study area. To this aim, the selected indicators have to be hierarchically ordered [19]. Such a hierarchy can be defined only in respect to a selected case study area, since it depends on the relevance of each indicator to each considered hazards. In detail, an indicator that is significant for all the considered hazards will have a greater weight than an indicator exclusively referred to a single hazard. Hence, physical vulnerability indicators, which generally refer to individual hazards (seismic, landslides, etc.) will generally have a lower weight in respect to other indicators, such as social (e.g., population age) or systemic vulnerability indicators (e.g., accessibility), which refer to multiple hazards.

Following this approach, the formula (3) can be redefined as follows:

$$VE = \sum e_{x,y,z} \left(\sum wv \right) \quad (4)$$

where w is the weight assumed by each vulnerability indicator, according to its relevance in respect to each hazard. Such relevance has been defined according to the selected scientific literature—that generally provides vulnerability indicators in respect to specific hazards—and measured according to a binary approach (yes/no).

4. The Case Study Area: A Multi-Hazard Urban Environment in Southern Italy

The case study area—the Phlegraean Fields, located in the western part of the metropolitan city of Naples, in Southern Italy (Figure 2)—represents a paradigmatic example of a multi-hazard urban environment: in addition to the volcanic hazards, this area is prone to several natural and man-made hazards and is characterized by a high population density and a relevant historical, archaeological and natural heritage. Moreover, it is worth noting that, compared to other volcanic areas characterized by a central volcanic system, such as the Vesuvian area, in the Phlegraean Fields, the area of possible opening of eruptive vents is very large, with significant consequences in terms of extension of the potentially affected territory [48].

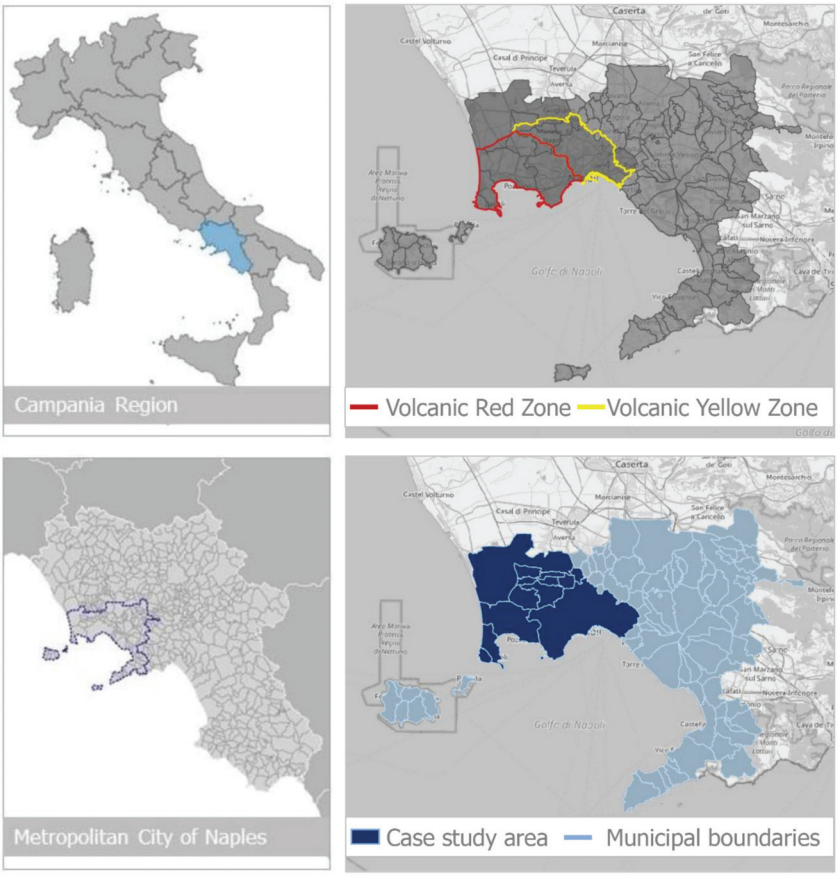

Figure 2. The case study area.

The selected case study area includes twelve municipalities: four of them are entirely included in the "red zone" of the Phlegraean Fields, which is classified as the highest risk area; the others are partially included in the red zone or included in the "yellow zone" (including part of the capital city of the Metropolitan area, that is the City of Naples), classified as areas at medium risk. Only one of the selected municipalities is not included in the volcanic area of the Phlegraean Fields: the Municipality of Qualiano. Nevertheless, the latter has been included in the case study area since, although not affected by volcanic hazard, it is enclosed between two municipalities partially included in the volcanic zone: Giuliano in Campania, partially included in the red zone, and Villaricca, which is part of the yellow zone.

Besides volcanic hazards, the case study area is also prone to other hazards, namely earthquakes, since all the selected municipalities are classified as areas at medium-high seismicity (corresponding to the seismic zone 2), landslides (10% of the overall territorial surface) and hydraulic hazard (10% of the overall surface). Moreover, the case study area hosts numerous hazardous industrial plants: 40% of the total hazardous industrial plants of the Metropolitan City of Naples are located in the case study area.

The twelve selected municipalities host more than 1,400,000 inhabitants (ISTAT 2019), which is about half of the inhabitants of the Metropolitan City of Naples, made up of 92 municipalities.

Once the case study area has been identified, all the available information on the different hazards that this area is prone to have been collected.

In particular, the case study area is prone to different sudden-onset hazards that, according to the terminology reported in numerous international documents (Hyogo framework, Sendai Framework, UNISDR Glossary 2004, 2016), can be classified as follows: geophysical hazards, whose origin is purely natural; hydrometeorological hazards, whose origin is however natural, but altered in different ways by anthropogenic pressures; anthropogenic hazards, such as industrial accidents, whose origin is purely anthropic (Table 2). Table 2 also shows the codes assigned to each hazard. The coding process is also adopted to identify the classes of elements at risk and the exposure and vulnerability indicators in order to combine all the data into the comprehensive exposure and vulnerability assessment.

Table 2. Considered typologies of hazards and codes.

Geological and Geophysical	**Code**
Earthquakes	Eq
Volcanic Eruptions	
lava flows	LF
pyroclastic flows	PF
ashes	As
Landslides	La
Hydrometeorological	
Floods	Fl
Extreme temperatures (heat waves)	HW
Anthropogenic	
Industrial accidents	IA

Then, the whole area has been preliminarily divided into homogeneous spatial units (HSUs), obtained through the overlapping into a GIS environment of census units provided by the Italian Institute of Statistics (ISTAT), Corine Land Cover areas and hazard levels, namely hydraulic and landslide hazard levels and volcanic classification, being the whole territory included in the same seismic zone (zone 2), according to the national seismic classification issued in April 2021 (Figure 3).

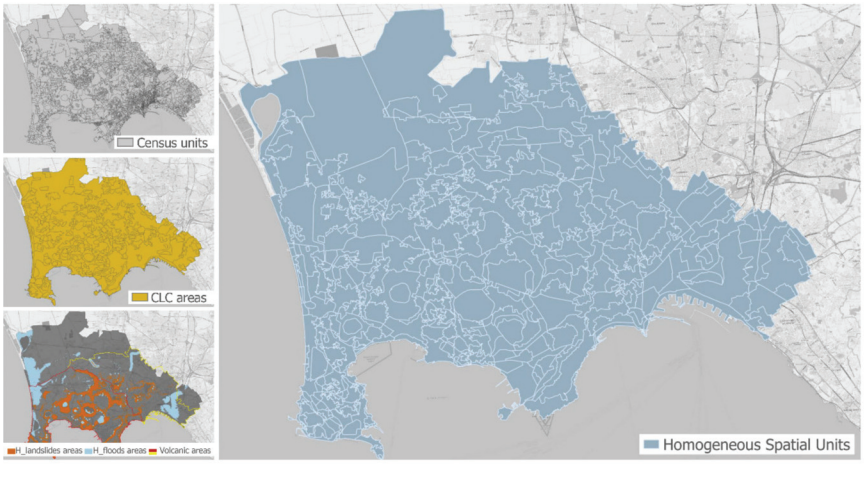

Figure 3. The case study areas divided into HSUs.

Then, according to the hazard features of the case study area, exposed targets have been identified and classified and, for each class of exposed elements, exposure and vulnerability indicators have been selected, based on the references provided in Table 1. The selected set of indicators (Table 3) is composed of:

- Indicators deriving from standard datasets (e.g., National Statistics, Copernicus) already available and spatialized, which only need to be systematized and homogenized. They can be easily reprocessed according to the different goals and scaled to different spatial units.
- Specific indicators referable to specific hazards or spatial scales that must be identified through devoted analysis (focus).

Table 3. Selected exposure and vulnerability indicators.

Classes of Exposed Elements	Exposure Indicators	Vulnerability Indicators	Vulnerability Dimensions	Data Sources
Residential areas	n° of residential buildings/total	Utilization degree	Physical	National Census
		Urban density	Physical	Copernicus HRL
		Construction type	Physical	National Census
		Imperviousness	Physical	Copernicus HRL
		Vegetation index	Physical	Copernicus HRL
		Conservation degree	Physical	National Census
		Age of buildings	Physical	National Census
		Buildings' material	Physical	National Census
		Number of storeys(height value)	Physical	National Census
Commercial, touristic, tertiary areas	n° of non-residential buildings/total	Utilization degree	Physical	National Census
		Urban density	Physical	Copernicus HRL
		Construction type	Physical	National Census
		Imperviousness	Physical	Copernicus HRL
		Vegetation index	Physical	Copernicus HRL
Urban Facilities	n° of buildings or areas	Hierarchical level	Systemic	Focus
		Strategic role	Systemic	Focus
		Accessibility	Systemic	Focus
		Redundancy	Systemic	Focus
Historical and cultural heritage	n° of building or site	Construction type	Physical	MiBACT database
		Imperviousness	Physical	Copernicus HRL
		Vegetation index	Physical	Copernicus HRL
		Cultural value	Systemic	MiBACT database
Transport infrastructure	length of roads	Hierarchical level	Systemic	Focus
	number of road access	Presence of bridges, tunnels or underpasses	Physical	OpenStreetMap
		Imperviousness	Physical	Copernicus HRL
	length of railways	Strategic role	Systemic	Focus
	n° of railway stations	Connectivity	Systemic	Focus
		Redundancy	Systemic	Focus
Industrial sites	n° of sites	Type of production	Physical	Regional registers
		Distances from residential/natural areas	Physical	Focus
Population	population density	Age—old age index	Social	National Census
		Education	Social	National Census
		Employment	Social	National Census
		Autonomy—% children and elderly	Social	National Census
		Immigrants and refugees	Social	National Census

The selected exposure and vulnerability indicators have been measured based on three main sources:

- The census data provided by the Italian Institute of Statistic (ISTAT). The national census provides, for each census unit, data on population (age, education, employment, etc.) and building stock (occupied or empty dwellings, age of buildings, etc.). Even though some census data at the municipal scale are permanently updated, data provided for individual census units are available only in respect to the last census, which dates to 2011.
- The Corine Land Cover layer released by Copernicus and updated to 2018, together with the Urban Atlas layer and the High-Resolution Layers, which provide useful data related to both imperviousness and tree cover density.
- The Open Street Map layers updated to 2020, integrated with other sources such as the Geonational web-GIS for information on educational facilities, the portal of the Ministry of Cultural Heritage (MiBACT) for the information on cultural heritage, the regional technical maps for the location and features of the transport network.

The raw data derived from these datasets have been associated with the HSUs previously identified and subsequently processed as exposure or vulnerability indicators.

All exposure and vulnerability indicators have been homogenized and normalized in a range from 0 to 1, according to the Formulas (1) and (2) (see Section 3).

The outputs of this process are single homogenized maps related to each selected indicator: in these maps, HSUs are ranked through normalized values of e', v' ranging from 0 to 1 (Figures 4 and 5).

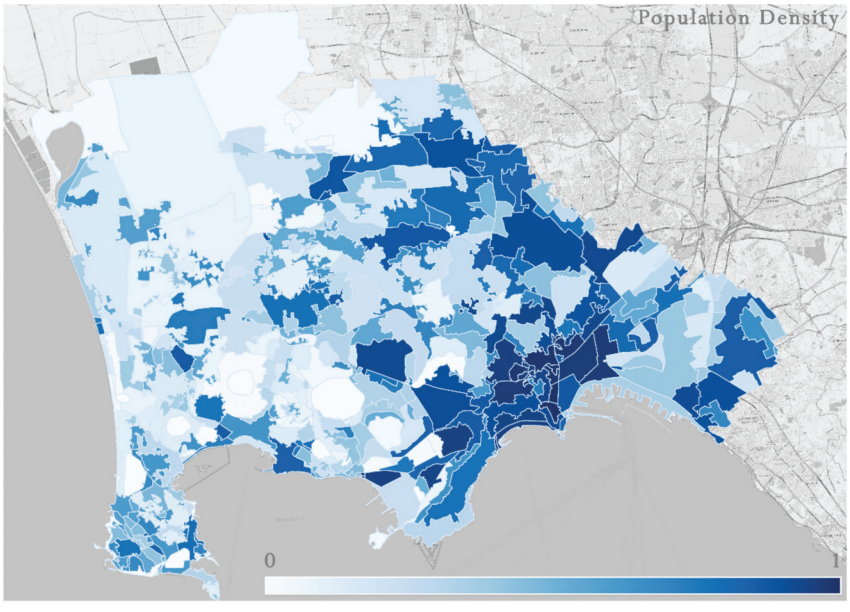

Figure 4. Maps of exposure and vulnerability: population density (exposure).

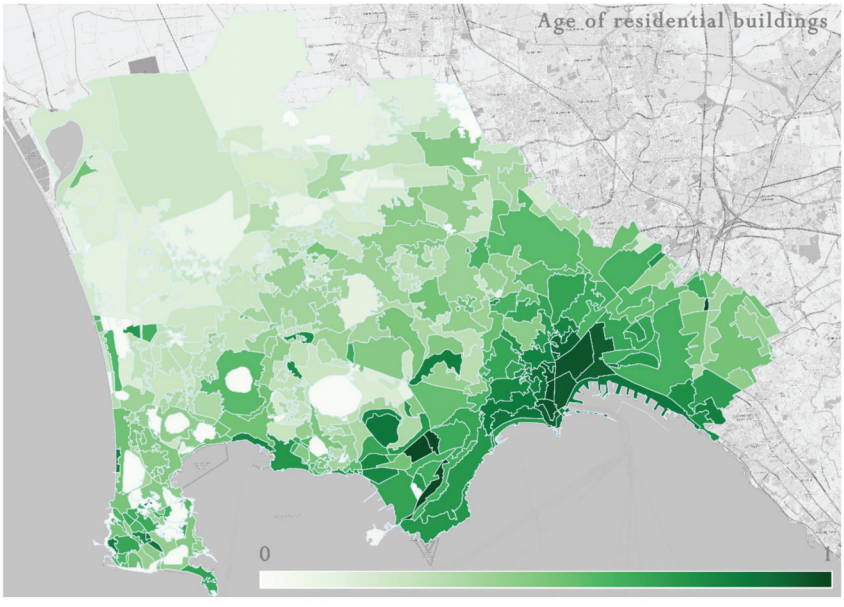

Figure 5. Maps of exposure and vulnerability: age of residential buildings (physical vulnerability).

Then, following the formula (3) (see Section 3), it is possible to carry out single EV maps for each class of exposed element in respect to each considered hazard. Figures 6 and 7 show the EV maps for residential areas and cultural heritage in the face of seismic hazard, respectively.

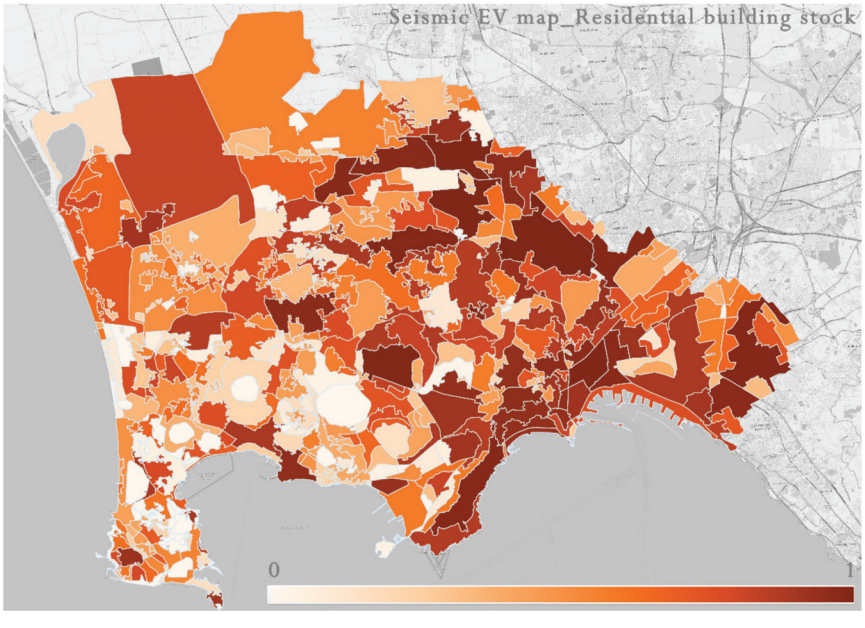

Figure 6. Exposure and vulnerability levels of residential building stock in the face of earthquakes.

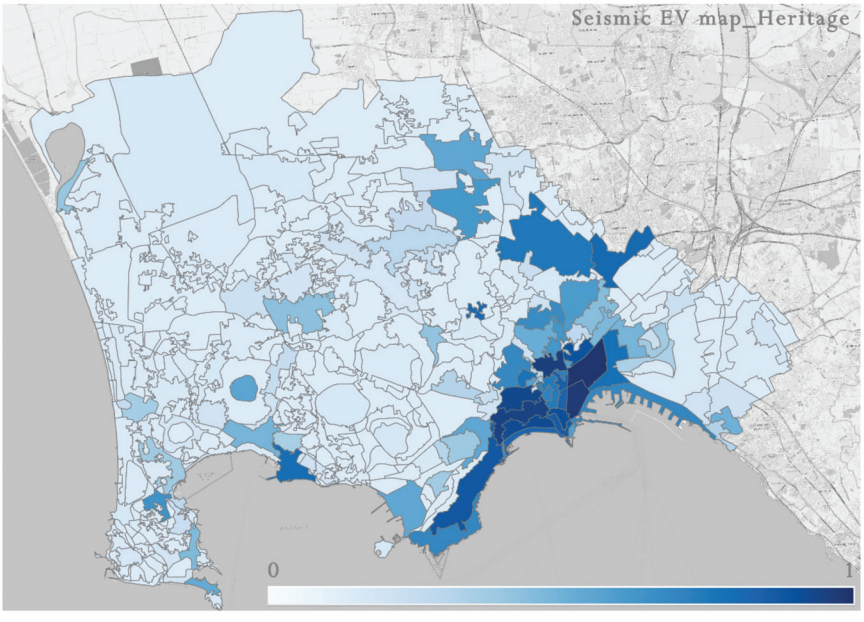

Figure 7. Exposure and vulnerability levels of cultural heritage in the face of earthquakes.

Finally, a summary value of exposure and vulnerability levels of each HSU in respect to all the hazards affecting the case study has been calculated by weighting each vulnerability indicator, according to its relevance in respect to each considered hazard (Table 4) and a comprehensive EV map for the case study area has been carried out (Figure 8).

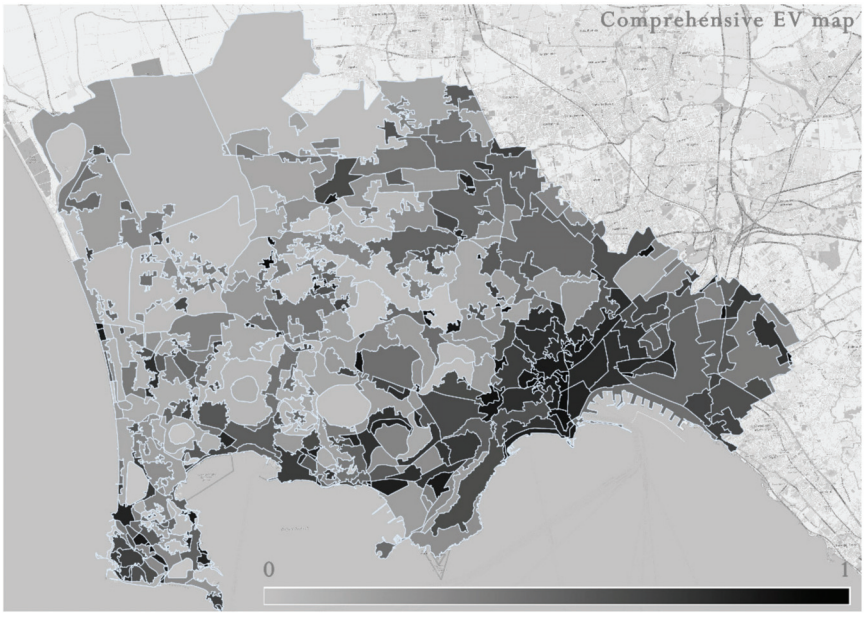

Figure 8. Comprehensive EV map.

Table 4. Indicators' weight according to the relevance for each hazard.

	Vulnerability Indicators	W								
		Eq	LF	PF	As	La	Fl	HW	IA	
Physical V	Utilization degree	■	■	■	■	■	■		■	0.88
	Urban density	■	■	■	■	■	■			0.75
	Construction type	■								0.13
	Imperviousness					■	■			0.25
	Vegetation index					■	■	■		0.38
	Conservation degree	■			■	■			■	0.50
	Age of buildings	■								0.13
	Buildings' material	■								0.13
	Number of storeys (height value)	■				■				0.25
	Presence of bridges, tunnels . . .	■	■	■	■	■	■			0.75
	Cultural value	■	■	■	■	■	■		■	0.88
	Type of production of industrial sites	■	■	■	■	■	■		■	0.88
Systemic V	Distances of industrial sites from . . .								■	0.13
	Hierarchical level	■	■	■	■	■	■		■	0.88
	Strategic role	■	■	■	■	■	■		■	0.88
	Accessibility	■	■	■	■	■	■		■	0.88
	Connectivity	■	■	■	■	■	■		■	0.88
	Redundancy	■	■	■	■	■	■		■	0.88
Social V	Age—old age index	■	■	■	■	■	■	■	■	1.00
	Education	■	■	■	■	■	■		■	0.88
	Employment	■	■	■	■	■	■		■	0.88
	Autonomy—% children and elderly	■	■	■	■	■	■		■	0.88
	Immigrants and refugees	■	■	■	■	■	■		■	0.88

A Focus on Systemic Vulnerability

As remarked in Section 3, systemic vulnerability indicators require in-depth and tailored-to-the-site analyses of features and roles of urban facilities and transport networks. In the case study area, it has been analysed according to a set of indicators related to:

- Location, redundancy, accessibility, hierarchical levels and role in emergency phase of urban facilities;
- Connectivity and redundancy of road and railway networks.

In particular, the hierarchical level of urban facilities has been defined according to the area served of each facility (regional, municipal, neighbourhood). The same criterion has been applied to the transport networks (e.g., a higher hierarchical level has been attributed to primary roads in respect to secondary and tertiary ones). Moreover, the strategic role of urban facilities has been defined according to their relevance in the emergency phase, in that the maximum value has been assigned to the facilities directly involved in emergency (e.g., hospitals, fire brigades, etc.). All this information can be easily collected from existing spatial plans at provincial/municipal scales as well as by emergency planning tools.

Accessibility levels depend on the relative distances between urban facilities and residential areas. The accessibility indicator refers to each HSU and has been calculated as the minimum physical distance on the road network between each facility and the closest residential areas.

Connectivity represents the degree of connection of each HSU to the primary road and railway networks. Connectivity has been measured through the physical distance of each HSU from the closest junction of the primary road network and the closest railway station and its value increases as the mutual distance decreases.

Redundancy refers to both urban facilities and transport networks. The former takes into account the presence of alternative facilities with a limited increase in travel time. The latter considers the presence of alternative routes to the main one.

According to these indicators, the systemic vulnerability levels in the case study areas have been defined as shown in Figure 9.

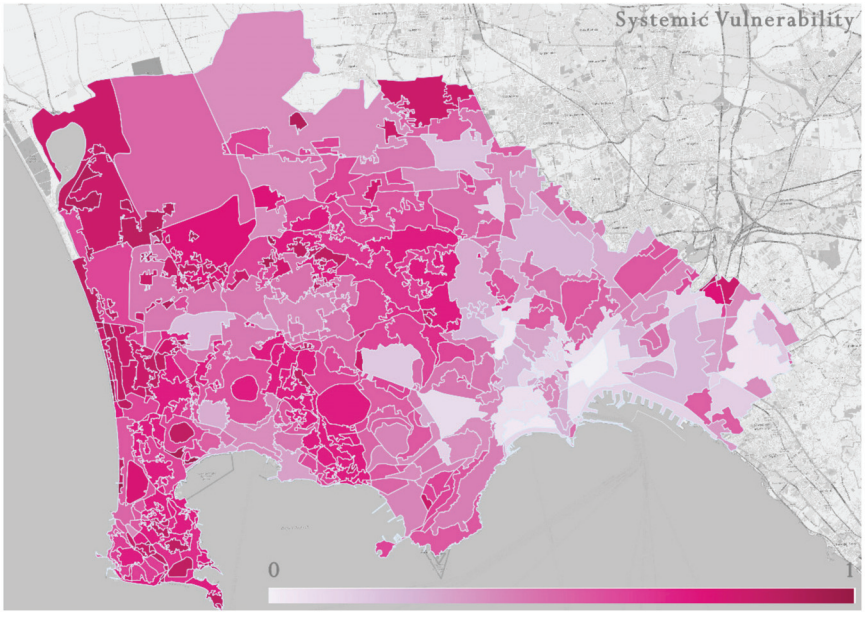

Figure 9. Systemic vulnerability levels.

As remarked in Section 3, the output maps provide different outcomes. In detail, comprehensive EV maps might allow prioritizing, according to a multi-hazard perspective, "hotspot" areas that require urgent measures to reduce exposure/vulnerability. These measures can be then outlined according to the output referred to the single EV maps, to the single classes of exposed elements in respect to individual/multiple hazards. These maps may support, for instance, risk-informed recovery and requalification strategies capable of reducing physical vulnerability of residential areas or cultural heritage in the face of seismic or flood events. It is worth noting that each output map may also allow identifying "thematic hotspot" areas related to the considered topics (e.g., exposure, physical, social, systemic vulnerability). For example, the systemic vulnerability map shows "thematic hotspot" areas, exclusively related to the selected set of systemic vulnerability indicators. These thematic hotspot areas differ from those identified by the Comprehensive EV map (Figure 8) that takes into account all exposure and vulnerability indicators in a multi-hazard perspective.

5. From Risk Knowledge to Risk-Informed Planning Strategies

As remarked above, planning strategies aimed at reducing multi-risk levels in urban environments require detailed information on the vulnerabilities of exposed assets and systems [3,9,10] that nowadays are often partially available, largely fragmented and difficult to combine each other. Thus, the outlined methodological path represents a first attempt to overcome the main shortcomings of available risk knowledge and to provide planners with homogeneous and update information on the different risk dimensions. Moreover, the "spatialization" of risk knowledge allows aggregating data and information at different scales: all data and information related to each HSUs can be, in fact, easily scaled up to municipal, provincial or even regional levels. Finally, the adoption of an indicator-based approach provides planners with a constantly updatable baseline against which the impacts of alternative planning choices on the overall levels of exposure and vulnerabilities as well as on specific risk dimensions (e.g., physical or systemic vulnerability) can be easily measured.

As remarked in Section 2, nowadays, risk knowledge as well as risk reduction strategies are mostly entrusted to sectoral authorities and tools (e.g., basin authorities, flood management plans), while spatial plans generally collect and assemble available knowledge without developing further analysis, and size their development choices to hints and constraints provided by sectoral plans, without a proper assessment of the impacts of alternative planning choices on current multi-risk levels and, namely, on exposure and vulnerabilities features of the area at stake. To date, while knowledge frameworks that planning tools are based on have been significantly enriched, including data and information related to numerous environmental issues (e.g., consistency and quality of natural resources), they still struggle to effectively embed risk knowledge. Moreover, adequate tools aimed at evaluating the impacts of alternative planning strategies on existing multi-risk levels are still often missing. Furthermore, the Strategic Environmental Assessment (SEA), a mandatory tool all over Europe for a wide range of plans and programs, still devotes limited attention to risk issues. While its crucial role in improving environmental protection in the EU has been clearly recognized [49] and numerous scholars have emphasized over time its potential for better integrating risk and more recently climate issues in spatial planning at different scales [50–53], SEA is still mostly focused on the impacts of alternative planning decisions on natural resources with a limited attention to determine whether they are likely to reduce/increase existing multi-risk levels.

Thus, even though the proposed methodology might represent a useful tool to support risk-informed spatial planning strategies, "plan-making" processes should be adequately revised to ensure a proper integration of risk issues in decision-making, with a particular attention to the relationships among sectoral and spatial plans as well as to the improvement of the current tools for plans and programs' evaluation.

In particular, the provided screening tool might be particularly relevant to determine whether urban regeneration policies are likely to have significant effects on existing exposure and vulnerability levels. According to the goals set by the Agenda 2030 and in line with the target of zero soil consumption by 2050, set by the European Commission [54], nowadays, planning processes are mostly oriented to regenerate existing settlements, often located in areas prone to multiple hazards. Hence, in the absence of an adequate multi-risk knowledge base against which the impacts of alternative planning strategies can be measured, and namely of disaggregate information on exposure and vulnerabilities in the face of different hazards, outlined strategies and measures may also result into an increase in current exposure and vulnerability levels in these areas. Moreover, the assessment of the likely impacts of alternative strategies and measures on current multi-risk levels would also contribute to deduct the decisions related to risk reduction from the purely technical domain to which they are generally entrusted and to favor, on the opposite, participatory processes and shared decisions on conflicting planning choices aimed, for example, at improving sustainability through the controversial practices of "densification" [55], which may increase, in turn, exposure and vulnerabilities to existing hazards.

6. Conclusions

This contribution provides a first answer, certainly not exhaustive, to the priorities set by the Sendai Framework and namely to the need of improving risk knowledge, by better using already existing knowledge as well as by taking into account all risk components (hazard, exposure and vulnerabilities), in a multi-risk perspective.

In detail, the research work has been addressed to set up a methodological path aimed at developing a comprehensive exposure and vulnerability assessment in multi-hazard urban environments, based on the significant outcomes so far provided by European research projects as well as by scientific literature focused on multi-risk and, above all, on vulnerability assessment. The methodological path has been tested on a case study area, the Phlegraen Fields, a multi-hazard urban area located in the western part of the metropolitan city of Naples, in Southern Italy.

It is worth underlining that even though all the key steps of the methodological path—hazards' identification and codification, selection of exposure and vulnerability indicators and their codification, normalization and spatialization, criteria for data aggregation to carry out heterogeneous output maps—have to be calibrated from time to time in respect to the geographical area at stake, it may represent a useful guide to better adapt existing risk knowledge to planning needs, allowing the building up of a "flexible" knowledge, capable of guiding and evaluating different planning strategies at different geographical scales. As all data and information are referred to in HSUs, output maps can be carried out in respect to HSUs or to their aggregations in larger units defined by administrative boundaries (e.g., municipalities) or land uses (e.g., urban areas) or hazardous areas (e.g., volcanic zones). Moreover, the different output maps (single EV maps referred to each indicator and to each hazard, EV maps referred to single classes of exposed elements and related to each hazard, comprehensive EV maps) are suitable to inform and assess different planning strategies: from new green corridors at a metropolitan/municipal scale, up to retrofitting interventions at a neighborhood scale. Furthermore, the systemic vulnerability map may represent a relevant guide to identify and strengthen the shortcomings of urban facilities, to support both a more effective emergency management and a better functioning of urban facilities in peace time.

However, the outlined methodological path also reveals some weaknesses: first of all, in order to set up a screening tool easily achievable starting from a "soft" reprocessing of data extracted from existing databases or at least through data elaboration into a GIS environment, some fine-grained indicators that, according to selected scientific literature, might be relevant in respect to specific hazards (e.g., ground-floors' usage, types of roofs) have been neglected, as they require detailed in situ analyses. Furthermore, the relevance of each indicator in respect to each hazard has been defined according to a binary approach (yes/no), which does not highlight the different levels of importance that each indicator may have in respect to each hazard. A more detailed assessment could be performed through specific estimation methods (e.g., multicriteria analysis) that could represent one of the future developments of the research work.

Finally, it is worth noting that the methodological path for a comprehensive exposure and vulnerability assessment represents only a first step towards a comprehensive multi-risk assessment. Further steps should devote more attention to the potential interactions among the different hazards that may influence each other, arising complex chains of secondary hazards, impacts and damage. However, the analysis of the mutual influences among hazards and vulnerabilities would require a shift from an indicator-based method to the development of risk scenarios.

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Conflicts of Interest: The authors declare no conflict of interest.

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Article

(Non)Environmental Alternative Action Organizations under the Impacts of the Global Financial Crisis: A Comparative European Perspective

Maria Kousis [1,*] and Katrin Uba [2]

[1] The University of Crete Research Centre for the Humanities, the Social and Education Sciences, 74100 Rethymno, Greece
[2] Department of Government, Uppsala University, 752 37 Uppsala, Sweden; katrin.uba@statsvet.uu.se
* Correspondence: kousis.m@uoc.gr

Abstract: Hard economic times have been considered obstacles for environmental activism by many environmental scholars, yet works, mostly based on case studies, on alternative action organizations (AAOs) during times of increasing livelihood vulnerability show considerable environmental activism. We explain this inconsistency by arguing that AAOs mobilizing at times of crisis opt for direct action, using strategies of citizens' solidarity initiatives centering on meeting basic needs and sustainability goals and thereby carry on the environmental claim-making in a new way. To this end, we compare environmental AAOs (EAAOs) with non-environmental ones using a cross-national dataset of 4157 hubs-retrieved AAOs active during the economic crisis (2007–2016), in France, Greece, Germany, Italy, Poland, Spain, Sweden, Switzerland, and the UK. Given that EAAOs constitute more than one-third of all AAOs, it is clear that environmental protection or sustainable development are not neglected even at times of economic hardships. Instead, the crisis provides an opportunity to broaden the scope of action for existing organizations that can adopt sustainability activities focusing on alternative practices and lifestyles, improving societal resilience. We further show that EAAOs tend to be informal and, to an extent, more concentrated on contention and protests than non-environmental organizations.

Keywords: alternative action organizations; environmental activism; solidarity; Europe; crisis; sustainability; alternative consumerism; alternative lifestyles; action organization analysis

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1. Introduction

Times of economic crises have been considered as periods of decreasing environmental concern and initiatives by many scholars [1] but also as periods of humanitarian crises [2]. Political institutions have been delaying environmental compliance in Europe and the US, as reflected in delays in auctioning of CO_2 certificates in the EU-emissions trading system or the CO_2 limits on automobiles, as well as in "midnight regulations relaxing environmental legislation" [3–5]. Simultaneously, civil society and citizens' environmental concerns for the crisis period show a notable decrease [6,7]. Development issues absorb environmental NGO activities with the environment becoming a non-central issue at times of economic downturns. The environment has played a very marginal role in the national elections as the public is more concerned about austerity policies and cuts in government expenditures [8], or welfare retrenchment and the economic crisis [5]. Only recently, scholars have shown how even in times of crises citizens' pro-environmental attitudes can remain important [9]. Furthermore, the latest youth protests for climate justice [10,11] suggest that environmental activism might be increasing regardless of other crises.

Nevertheless, within this context, as well as subsequent crises that followed the economic crisis-the so-called "refugee crisis" of 2015 and the pan-syndemic of 2019 [12], recent work on the environmental movement points to their heterogeneity, their ability to

profoundly transform themselves and to their increasing institutionalization [13]. Furthermore, scholars studying alternative solidarity activism, have suggested that changes have been taking place and that there is significant environmental activism, especially when looking at mutual-help and bottom-up grassroots actions which offer alternatives to the mainstream capitalist economy [14–18]. There have been many examples of environment related direct action [19–21] and everyday activism [22–24], both before and during the past decade of crises (e.g., global financial, Eurozone, refugee, political, and climate crises). Although scholars note that environmental movements have moved beyond nature and conservation, to alternative consumption, extractivism, and climate justice [13], there are only few comparative empirical studies which actually demonstrate this change.

We address these different trends in the literature and argue that this period of ever-increasing inequalities [25] points to the need of refining analytical tools to bring to surface facets of alternative environmental activism that have received limited attention thus far [26]. We complement the existing studies related to climate justice, green backlash, and global environmental justice [14,27–29] by centering on a field of alternative action initiatives organized to confront hard economic times [17].

Neither the environmental nor the solidarity/social innovation strands of the literature offer a comparative systematic account of alternative environment-related solidarity organizations during hard times, across different national settings. This would be, however, important as solidarity actions developed during such times could also be useful for hard times such as during the health and climate crises, or in cases of natural or man-made disasters. We therefore aim to contribute by addressing this gap with empirical data from a comparative European Commission project, shedding light on a less visible field of environmental activism engaged in participatory solidarity initiatives reflecting economic, environmental as well as a socio-political transformative capacity, mostly at the local level.

More specifically, we analyze a cross national database built on Action Organization Analysis [30] and offer a descriptive, exploratory account comparing Environmental versus Non-environmental AAOs for nine European countries, during the period of the economic crisis (2007–2015). The systematic analysis offers a documented account of the major organizational characteristics, their aims as well as the strategies and actions they used to mitigate the risks and manage the vulnerabilities of the global economic crisis of 2007. It will also illustrate to what extent AAOs address environmental concerns and can thereby be considered part of the environmental movement. The discussion will also address the implications of the findings for AAOs' resilience when examining the impacts of the economic crisis.

2. Literature Review: Solidarity and Environmental Activism during Hard Times

Scholars of environmental activism in European settings adopt diverse theoretical and conceptual perspectives, as revealed in a multi-faceted literature. However, views appear to converge when defining the environmental movement [31–33] and approximate Charles Tilly's durable definition of social movements, as 'sustained challenges to power-holders in the name of interested populations, which appear in the form of professional movements, ad hoc community-based, or specialized movements, and communitarian, unspecialized movements, that give rise to a new community' [34] p. 18. Three basic forms of the environmental movement are acknowledged: formal environmental movement organizations; grassroots, community-linked groups; and radical, highly committed ecological groups. Alternative definitions of the environmental movement, adhering to European theoretical traditions have been proposed [35], following Mario Diani's definition of social movements (including environmental ones) as 'networks of informal interactions between a plurality of individuals, groups and organizations, engaged in a political or cultural conflict, on the basis of a shared identity' [13,34]. For others [36], collective identities, or narrative constructions which enable controlling the boundaries of a network of actors, are critical in the study of the environmental movement.

In terms of the succeeding waves of environmentalism [32] and types of environmental organizations involved, a simplified typology reveals a succession of conservationism, environmentalism and ecologism [37]. Other scholars have also included grassroots environmental movements [28,38–40]. Although useful, this categorization and periodization only rarely takes into account the significant changes in society, particularly the various critical moments, crises (e.g., global financial, climate crises), natural or manmade disasters or increasing inequalities [41,42]. This points to the need of refining analytical tools to bring to surface facets of environmental activism that have received limited attention [13,26]. Thus, we aim to offer a comparative account of environmental and nonenvironmental AAOs. The comparative findings will strengthen our knowledge on alternative forms of action and will thereby contribute towards our understanding of the ways in which ad hoc citizen initiatives surface as collective resilience organizing to cope with the crisis.

Diverse repertoires of citizens' direct solidarity actions and aims, with economic as well as a socio-political transformative capacity, appear usually during hard times as alternatives to the mainstream/dominant capitalist economy, or as initiatives aiming at building autonomous communities [17]. AAOs usually flourish during hard economic times marked by austerity policies, multiple, compound inequalities, governance problems, the weakening of social policies, as well as the depletion of labor and social welfare rights [19,20]. AAOs range from the more reformist third sector organizations, to social solidarity economy, critical geographies and post-capitalist ones [17].

Such initiatives have been studied as social innovation [43], social, human, and solidarity economy [44], political consumer oriented sustainable community movement organizations [15], communitarian forms of political consumerism [45], alternative economic practices [46], de-growth [47], alternative geographies [48], and post-capitalist and anarchist initiatives [48,49]. However, more recently these are bought under one umbrella term-AAO to embrace the variety of alternative forms of resilience [17,30]. The strategies of AAOs vary, but usually involve diverse repertoires of citizens' direct solidarity actions.

Even though such organizations are discussed in the recent literature of sustainability [50,51], there is a lack of systematic comparative analyses documenting the extent to which these organizations are environmentally active in European countries or how these may promote resilience in the context of the crisis. It has been shown that those South European countries harder hit by the crisis–Greece and Spain-witnessed higher peaks in newly created alternative organizations and groups, while at the same time, their initiatives tended to be organized more frequently by informal and protest groups compared to those in the other countries [19,52,53]. According to the theories and prior research relating the economic crisis to the declining support for environmentalism [7], one would also expect that in such countries AAOs would not be as concerned for the environment as those in the countries least affected by the economic crisis (e.g., Germany or Sweden). Similarly, one would expect that the AAOs established at times of crises are less, or differently focused on the environment.

In addition to the crisis, other contextual factors might also affect the development of environmental AAOs. In particular, historical conditions influence the organizational formations, resources and strength or effectiveness of the environmental organizations and movements in specific countries. On one hand, the presence of many strong environmental movements refers to the presence of open opportunity structures for such movements and might facilitate the mobilization or organizing of environment related AAOs. On the other hand, the existing organizations might also cover the "problem areas" the AAOs would work in and this might also lead to a smaller number of AAOs.

The nine countries in this study had a varying strength of (professionally oriented) environmental social movements in the late 70s and 80s. For example, Germany and Switzerland could be considered very strong, while Sweden, Spain, and France as medium strong; the UK, Italy, and Greece were seen as having relatively weaker overall strength of environmental social movement mobilization [54]. Prior studies rarely focus on East European countries such as Poland, which we have included in the analysis. It could be

assumed that during the 70s and 80s the environmental movement in Poland was also under formation [55].

More importantly, this literature centers its attention to formal, more professional environmental social movement organizations emerging under different opportunities and national historical conditions affecting their growth. However, other works point out the importance of community-based [34] more informal, grassroots, citizen-consumer environmental movements appearing under different historical context, usually with more limited resources, in less resourced regions, as seen in the environmental justice, or alternative action literature [14,16,28,39,56]. Considering that the constituencies of AAOs tend to be citizen-consumers, small enterprises, local communities, and vulnerable groups, i.e., groups close to the constituencies of social movement organizations [57], it is likely that environmental AAOs are also rather similar to environmental social movement organizations in respect to their constituencies.

Furthermore, we expect that environmental AAOs are more protest oriented compared to those not focused on the environment, and opt for bottom-up rather than top-down solidarity approaches. This is similar to what is suggested by Lorenzini [58], who refers to the importance of political consumerism, lifestyle politics, food activism, and alternative lifestyles in the environmental movement. She considers forms of action such as citizens buying goods and services following their ideological views, alternatives to the mainstream market (e.g., fair trade goods, organic food), but also engaging in community-supported agriculture to be more far-reaching and part of the environmental movement. Many of such activities are typical for AAOs [17]. There probably will be cross-national variations, but the variation of major constituency groups of AAOs is rather related to the solidarity orientation of the organization than to country characteristics [57].

In addition, based on work by de Moor and colleagues [21] using ethnographic case studies, the post-political context in which these organizations operate has been found to lead to depoliticization; yet, activists adopt strategies to maximize their political impact. For Moor et al., the political character or degree of (de)politization of EAAOs could be evaluated by focusing on three dimensions of the "political": (1) motivations or goals of the movement (challenge existing capitalist order), (2) activists' views on agonism, and (3) movement strategies (the more contentious, the more political). Since our EAAOs almost by definition include organizations that aim to promote alternative economic and noneconomic practices, it is reasonable to evaluate only their third dimension of "political"–the degree of contentiousness or protest orientation. We propose therefore that EAAOs organize direct collective actions, at times combined with contentious actions, both leading to empowerment and common goals, which are important for collective resilience [59–61]. It was also proposed that the activities of AAOs reflect the wide repertoire of organizations forming Alternative Forms of Resilience [17].

3. Materials and Methods

Based on a new approach, Action Organization Analysis (AOA) [30], we have located a universe of the organizations via online directories (hub-websites) of AAO organizational websites for each of the nine countries in our study. AOA has been created in the context of the project "Living with Hard Times: How Citizens React to Economic Crises and Their Social and Political Consequences" (LIVEWHAT). Aiming towards a comprehensive and systematic study of AAOs in the context of the economic crisis, the project has developed and applied the method to study alternative initiatives and solidarity practices during the years of the global financial crisis (2007–2015) in France, Germany, Greece, Italy, Spain, Poland, Sweden, Switzerland and the UK. Identifying adequate sources which would allow for the mapping and systematic study of AAOs at the national and cross-national level has previously generated challenges for the researchers since these are difficult to locate in sources allowing for systematic empirical research (as in protest event or organizational studies) at the national level.

Retrieving websites from hubs (online directories) allows AOA to avoid the prior limitations in identifying such initiatives which usually include informal grassroots groups in newspapers or conventional archives. It therefore allows for a more comprehensive coverage compared to national newspaper reports or local newspaper reports. AOA offers live updated directories, which are more inclusive of informal as well as formal organizations compared to conventional sources [62]. Hubs incorporate a considerable number of AAO websites, including rural or less resourced groups. In contrast to the more selective focus of other online-based approaches, the hubs-website approach provides large numbers of links on action organizations and an approximate 'population' from which randomized and cleaned samples can be drawn, not only for website and AO coding, but also for supplementary online-surveys and qualitative interviews [63,64]. The approximate population was used for drawing a random sample of 500 AAOs from each country; coding the characteristic of the AAOs followed, based on a common Codebook created for the specific study [30,65]. The home-pages of selected AAOs were coded by native speakers during 2016. It should be noted that the AAOs that had a Facebook group but not a webpage, were not included in the dataset.

The selected AAOs had to be active during the recent global economic crisis (2007–2016) and active in any of the following ten main types of alternative solidarity activities:

- basic and urgent needs (related to food, shelter, medical services, clothing, free legal advice and anti-eviction initiatives),
- economy (involving alternative coins, barter clubs, financial support, products and service provision on low prices, fundraising activities, second-hand shops and bazaars),
- energy and environment (protection of the environment or wild life, focus on renewable energy, climate change, anti-carbon, anti-nuclear power, waste management, recycling or animal rights),
- alternative consumption such as producer-consumer actions, community gardens, boycotts and buycotts
- interest group advocacy,
- self-organized spaces,
- culture and education,
- civic media,
- actions for preventing hate crime or
- to stop human trafficking [65].

We note that even though our limited time and resources had not allowed coding EAAOs for a longer period (e.g., 2000–2016),unlike a survey, the AOA approach that codes information from the AAO's organizational website, allows us to analyze EAAOs based on their year of establishment and the year of creation of their organizational website. We can therefore trace and illustrate which EAAOs were established each year, from 2007 to 2016. We expected fewer organizations in the first years of the crisis and an increasing number from 2009 onwards.

Defining Environmental AAOs

For the purposes of the analysis at hand we have only selected 'environmentally active' AAOs which included any of the following environment related solidarity activities: energy and the environment, alternative consumption, food sovereignty, or alternative lifestyles related solidarity activities (at the time of coding, in the past, or planned in the future). Their profile, is very similar to the environmental AAOs described by other scholars [21], that is, they focus on the promotion of "sustainable materialism" [33].

Subsequently, in our dataset of 4157 AAOs, more than one third (35%), that is, 1461 AAOs were labelled as environmental AAOs (EAAOs thereafter). While half of these deal with alternative consumption, food sovereignty or alternative lifestyles' related solidarity activities, 28% focus primarily on energy and environment and the rest (22%) are involved in both of these sustainable activities. More specifically, these energy and environment related solidarity actions involve: protection of environment or wild life

(31%); renewable energy or climate change (13%); anti-carbon or anti-nuclear energy (3%); waste management (14%); and protecting animal rights (7%). The alternative consumption actions primarily include activities such as community agriculture (44%), DIY and "slow food" actions (15%), community gardens (8%), alternative transportation (2%), alternative lifestyle and consumption (15%); building autonomous solutions and de-growth promotion (5%). As our coding procedure allowed coders to code the different types of solidarity activities that were mentioned on the organizational websites, we find that while non-environmental AAOs in general have 2.0 activities on average, EAAOs have 2.7 activities on average. This suggests that these EAAOs are more diverse in their actions. For example, while only 15% of energy and environment related EAAOs use such activities, 10% combine their energy or environment related activities with cultural or education related activities and another 10% use economic solidarity in combination to environmental, or energy related actions. Furthermore, our coders were also able to identify the main solidarity activity for more than 61% of the EAAOs (the respective number of AAOs is 57%). This allows us to report that a significant majority (64%) of EAAOs actually had their primary solidarity action related to energy or environment, alternative consumption or both.

As our dataset also includes the year of foundation of the organization for about 70% of the AAOs and 76% of EAAOs, we find that half of the AAOs in the study were founded since 2005, before the crisis, while the respective year for EAAOs was 2007, when the crisis had just begun. It is also noteworthy, that out of 247 AAOs founded in 2011, when the impacts of the crisis were deeply experienced at the community level, 47% were EAAOs.

An alternative option to the categorization based on solidarity activities would be the use of the AAO's aims stated in its website. About 22% of the AAOs in our total sample and 53% of the EAAOs stated (in the website) that their goal was to promote sustainable development, and the respective percentages were 42% and 74% for alternative economic and non-economic practices or lifestyles. We focus on activities rather than aims because the activities are a stronger indicator of the environmental profile of an organization, as they refer to the concrete direct activities aimed at achieving pro-environmental social change.

4. Results and Discussion

Our findings below provide a comparative account of environmental and non-environmental AAOs, their organizational profile, their aims, as well as the strategies and actions they have used to mitigate the risks and manage the vulnerabilities of the global economic crisis of 2007. They also illustrate the extent to which AAOs address environmental concerns and can thereby be considered part of the environmental movement.

4.1. Who Are the AAOs and to What Extent Are They Environment Oriented?

In order to get a better view of the character of our EAAOs, we have examined their type (Table 1) and solidarity approach (Table 2). As one would expect, these are more frequently organizations of social economy (e.g., The Ants in Sweden or Club "Brotherhood and Peace" in Italy), informal and/or protest groups (e.g., transition Matlock in the UK or vegan Solidarity Kitchen in Germany). The large proportion of NGOs suggests that we deal with rather typical environmental organizations, or environmental social movement organizations. In the context of crisis, the solidarity approaches which the organizations adopt are crucial and therefore one would expect that EAAOs focus on mutual help rather distribution of goods and services (Table 2).

Indeed, EAAOs are focusing primarily on bottom up and mutual help, especially in comparison with non-environmental AAOs, which tend to adopt a solidarity approach that is more top-down oriented, offering services and goods to beneficiaries/participants (Table 3). Similarly to the literature on environmental sustainability, our investigation shows that AAOs focusing on environmental sustainability actions are also the ones which work for and with consumers, small enterprises and local community. Thus, similarly to the findings by Uba and Kousis [57], showing that the constituencies of AAOs in general are close to the ones of social movement organizations, the beneficiaries of the environmental

AAOs during times of crisis in Europe are rather similar to those of environmental activists and movements. Both focus considerably on consumers as participants of AAOs.

Table 1. Organization Type of EAAOs and non-EAAOs (percentages).

Type	Env. AAOs (%)	Non-EAAOs (%)
NGOs	41	31
Informal and/or protest gr.	28	14
Informal platform	2	3
Social economy	21	16
Charities, church	5	20
Trade unions	0.4	0.45
Other	11	5
All	100% (1461)	100% (2696)

Table 2. Solidarity approach of EAAOs and non-EAAOs (percentages).

Type of Solidarity	Env. AAOs (%)	Non-EAAOs (%)
Mobilizing for mutual help	69	39
Support between groups	29	17
Offer support to others	26	49
Distribution goods/services	33	55
Total N (percentages go over 100%, as multiple selection was allowed in the pre-defined list)	1461	2696

Table 3. Constituency groups of EAAOs and non-EAAOs (percentages).

Constituency Groups (Not Mutually Exclusive)	Env. AAOs (%)	Non-EAAOs (%)
Animals	3	0.01
Children/teens/young/students	19	25
Consumers	23	3
Disabled/elderly	2	9
General population	13	13
Local community	9	4
Poor	6	9
Small enterprise	16	4
Refugees/migrants	3	6
Total number of AAOs (does not add to 100% given dichotomous variables, multiple answers allowed)	1461	2696

Looking at the year of foundation of the organization (Figure 1), we find that the average age for the AAOs is 18.3 years, while for EAAOs it is 14.8 years. Even though information is missing for about 30% of AAOs, and 24% of EAAOs, the available data reveal that the large proportion of EAAOs were founded in relation to the crisis, after 2007.

Figure 2 illustrates the number and proportion of the types of EAAOs and non-EAAOs founded since 1991. Based on our AOA approach, the figure documents that organizations which were founded almost two decades before the global financial crisis, were organizing solidarity activities during the crisis period–coded in 2016.

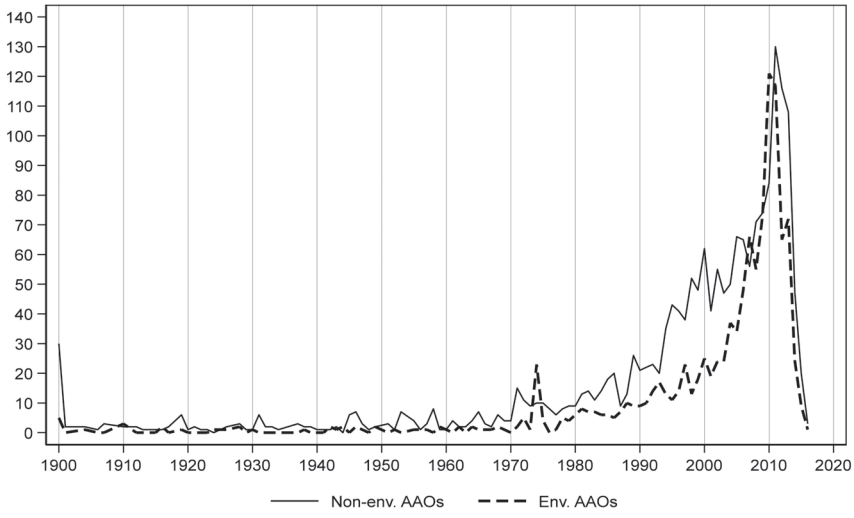

Figure 1. Year of Foundation of EAAOs and non-EAAOs, as a proportion of all AAOs (N = 2963).

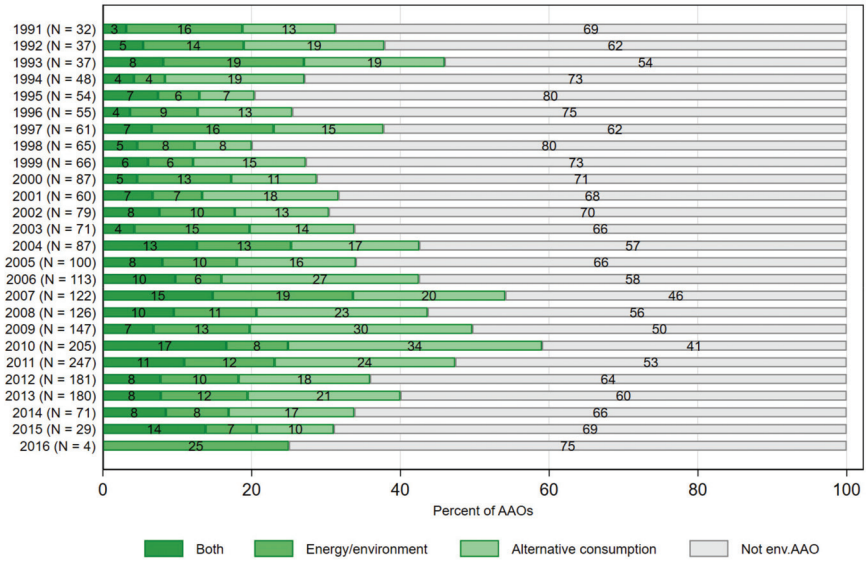

Figure 2. Number and Proportion of types of EAAOs and non-EAAOs founded since 1991.

The data above therefore show that a large proportion of AAOs, which were founded since the economic crisis, organized activities related to energy, environment, alternative consumption, or both. We do not argue that the existing organizations changed their strategies towards more participatory solidarity, as we do not investigate all kinds of organizations over time. Our argument that the studied AAOs (as well as EAAOs) mobilize during times of crisis is based on, (a) our sampling strategy of selecting organizations active during the global financial crisis (2007–2016), (b) the evidence that the number of AAOs in general increased during the years following the economic crisis, and (c) that the large proportion of the AAOs founded since the beginning of the crisis (2007) were environment oriented (EAAOs).

4.2. Which Aims Drive (Non)Environmental AAOs to Mitigate the Risks of the Economic Crisis?

In addition to the expected sustainable development aims, EAAOs are also more likely to promote alternative lifestyles than non-environmental AAOs (Table 4). Even though these are AAOs active in times of economic crisis, a significantly smaller proportion of EAAOs, compared to other AAOs, aim primarily to reduce the negative effects of economic crisis or reduce poverty and exclusion. Although they might promote such goals indirectly via their activities, it is noteworthy that the explicit focus on crisis mitigation is not visible in their organizational websites. On the one hand, this partly reflects the criticism towards traditional environmental organizations, that they are not addressing grassroots concerns. It could also imply that EAAO claims about "crisis" are related to the emergent discourse of "climate crisis" rather than the explicit "struggle" for grassroots concerns on meeting basic needs at the community level. On the other hand, the aims of promoting alternative economic and non-economic practices and lifestyles are implicitly thought to address the concerns of people with lower socioeconomic status.

Table 4. The Aims of EAAOs and non-EAAOs (percentages).

Aims (Not Mutually Exclusive)	Env. AAOs (%)	Non-EAAOs (%)
To reduce the negative impacts of the economic crisis/austerity	9	12
To reduce poverty and exclusion	16	35
To combat discrimination/promote equality of participation	12	29
To increase tolerance & mutual understanding	7	18
To promote alternative economic practices, lifestyles	63	15
To promote and achieve social change	31	31
To promote and achieve individual change	17	37
To promote sustainable development	53	5
To promote health, education, welfare	15	34
To promote alternative noneconomic practices, lifestyles and values	22	12
To promote democratic practices	18	21
To promote social movement actions and collective identities	10	9
Total N (percentages go over 100%, as multiple selection was allowed in the pre-defined list of aims)	1461	2696

Under the impact of the economic crisis, the majority of AAOs–clearly focus on alternative economic practices;nevertheless, significant cross-national variations do exist (see Figures 3 and 4). The EAAOs are clearly more focused on alternative lifestyles and sustainable development than other AAOs across the nine countries; however, the proportions are the lowest for alternative lifestyle in the former communist country, Poland. The aim to promote sustainable development among Greek and Spanish EAAOs is relatively low, but expected since these countries were the most affected by the economic crisis. This can be seen even in the focus of EAAOs on the economic dimension (18% and 22% of the EAAOs in the respective countries), which aimed to reduce the negative effects of the economic crisis, while in other countries this varied from 0–15%.

The cross-national variation of EAAOs (as a proportion of all AAOs) in Figure 5, shows the divisions by solidarity activity (energy or environment, alternative consumption, or both). Examples of EAAOs focusing mainly of energy and environment, are the German Animal Welfare Federation, the Rural Youth Union from Poland, or the IPF New Energies from France. EAAOs focusing on solidarity and alternative consumption are, for example, organizations that promote second-hand shops, such as several religious organizations in Sweden or Switzerland, as well as the ones supporting organic farming and food (e.g., Gardens of Cocagne in France, or Greencity Wholefoods in the UK). Among EAAOs with solidarity activities related both to environment & energy, as well as alternative

consumption are organizations such as Global Justice Now in the UK, Cultural Association of Ano Ambelokipi in Greece, The City Quarter Inverigo from Italy, or a vegan solidarity kitchen in Germany.

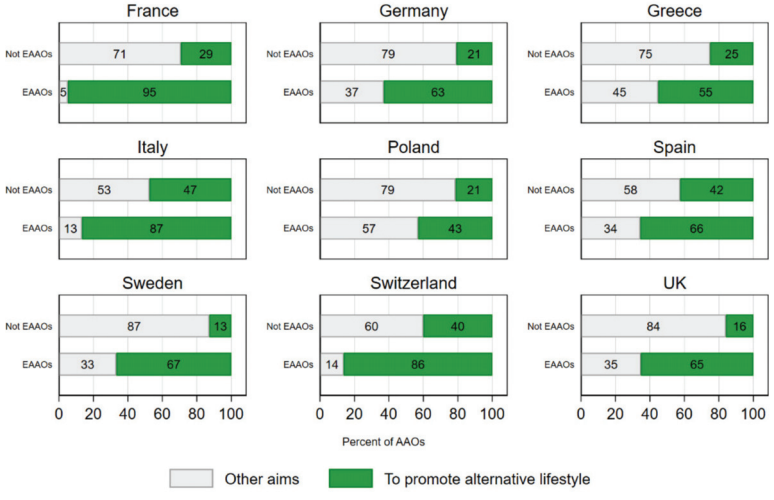

Figure 3. Aim to promote alternative lifestyles of EAAOs and non-EAAOs, by country.

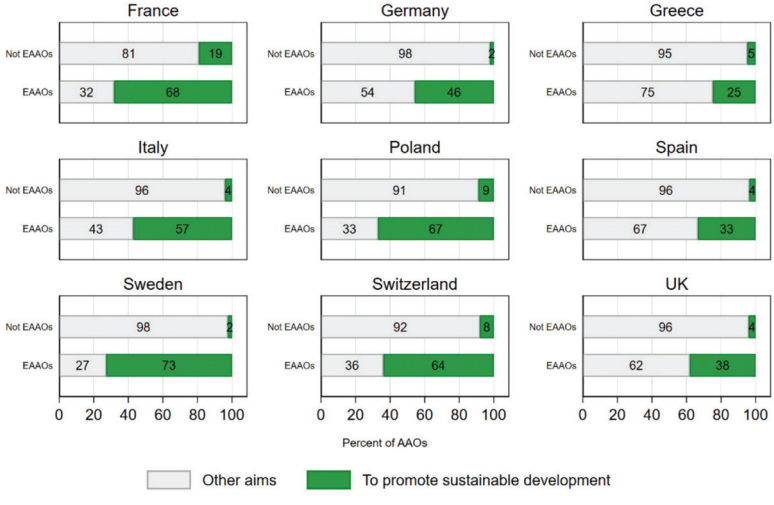

Figure 4. Aim to promote alternative lifestyles of EAAOs and non-EAAOs, by country.

There are very clear differences between Germany, with a relatively few environmental AAOs and Switzerland, where almost half of the AAOs have energy, environmental or alternative consumption related activities. The same applies for Sweden and France, suggesting that the historical strength of the environmental movement is not directly related to the activism of environmental AAOs during times of crisis. When we look at the age of the EAAOs in the examined countries, that is the time between coding (2016) and the year of foundation as reported in the EAAOs' website, then there are some cross-national variations as well. In France, Greece, and the UK, the EAAOs are significantly younger than non-EAAOs, while in other countries there is no such difference. Still, none of these

differences demonstrate any clear patterns which follow the strength of environmental movements or exposure to the economic crisis.

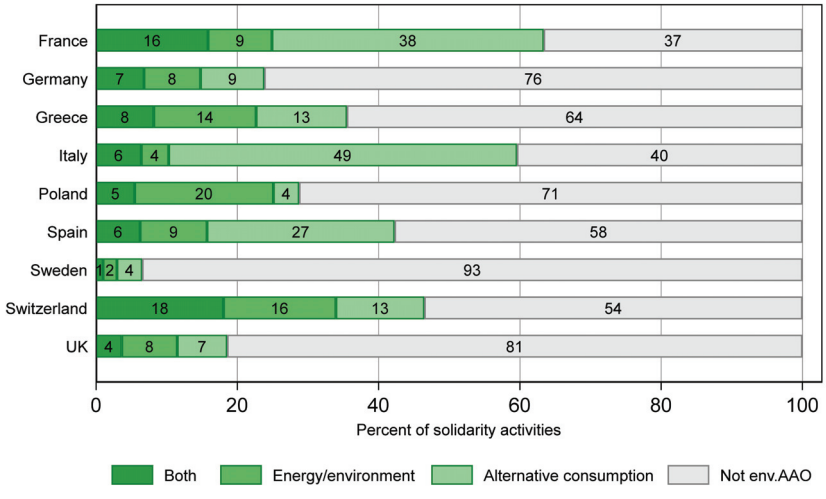

Figure 5. AAOs' Environment and non-Environment solidarity actions, by country.

4.3. Through Which Strategies and Actions Do (Non)Environmental AAOs Manage Vulnerabilities during the Economic Crisis?

Aiming to categorize the EAAOs on the basis of the degree of (de)politization, we have followed the discussion in de Moor et al. [21] on the three dimensions of their political character (motivations or goals of the movement; perceptions of activists regarding agonism; strategies of the movement—the more contentious the more political. This would suggest that an EAAO could be political to different degrees–some are "political" in their motivations only, where others are "political" in all three aspects. As our EAAOs almost by definition include organizations that aim to promote alternative economic and alternative noneconomic practice, we rather evaluate the third dimension of the "political". Hence, we look at the strategies or preferred routes to reach the organization's aims, and the degree of contentiousness of these strategies. We label as "contentious" all EAAOs which report (in their website) that their preferred route for achieving their goals are protests or change of establishment, while we categorize non-EAAOs as those preferring "direct action", raising awareness, or reforms.

The results of this categorization are presented in Table 5 and Figure 4. These show that a relatively small proportion (16%) of EAAOs could be labelled as "political" on the basis of the de Moor et al. [21] third dimension, but this also reflects the general character of the AAOs in our sample. Still, the difference is significant and suggests that the EAAOs that are active in times of economic crisis, are more political than other AAOs. In contrast, the majority of the AAOs aim to reach their goals via direct action.

Table 5. Type of strategies by EAAOs and non-EAAOs (percentages).

Type of Strategies	Env. AAOs (%)	Non-EAAOs (%)
Contentious (protests)	16	12
Direct Action	72	80
Raise awareness	5	5
Reform	7	3
Total	100% (1461)	100% (2696)

The cross-national variations are also noteworthy (see Figure 6). On one hand, in Greece, Poland, Switzerland and the UK, the EAAOs are significantly more contentious than other AAOs. On the other hand, particularly low degree of contentiousness could be found among the EAAOs in France, Germany, Sweden, and the UK. The relatively high degree of contentiousness probably reflects the effect of the economic crisis, as the most affected countries were Greece, Spain, and Italy. The finding that EAAOs in some countries are more political than other AAOs should be examined further, as these might also be more revealing about the policies such organizations promote. Although the direct actions—i.e., the dominant strategy for EAAOs and other AAOs -, often aim for social transformations outside the parliamentary sphere [20], using contentious strategies is more typical for traditional social movements, and might lead to requested public opinion or policy changes faster than using only direct action.

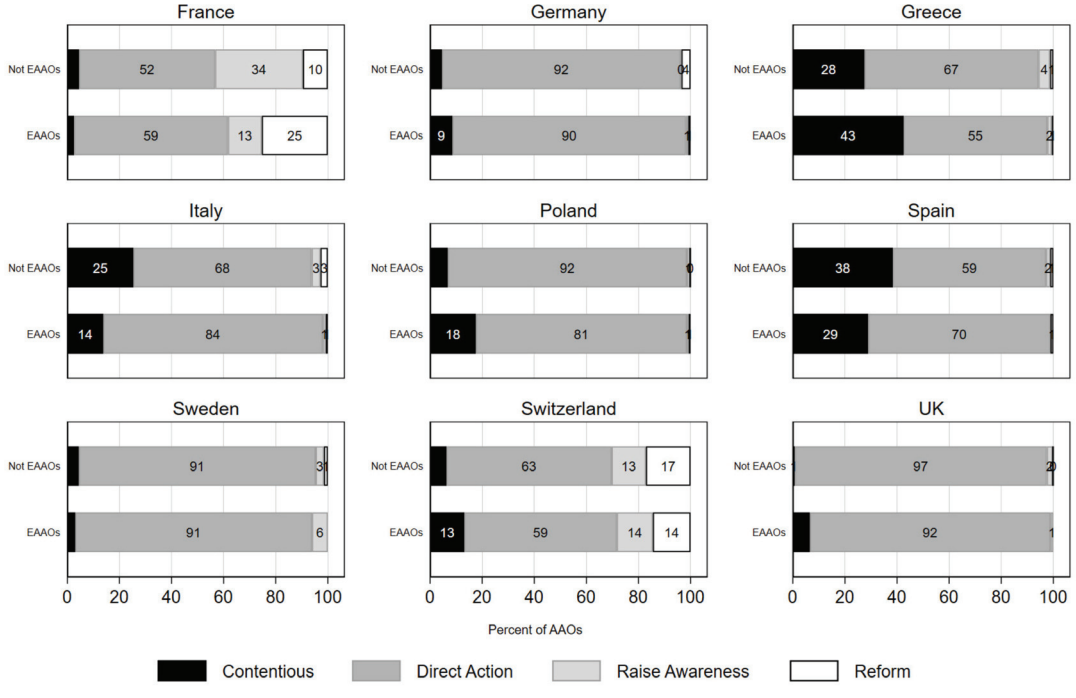

Figure 6. AAOs' Environment and non-Environment solidarity actions, by country.

5. Conclusions

Using primary comparative data on AAOs from nine European countries, the paper points out the importance of environmentally active communities which are confronting hard times through a more participatory solidarity approach. Their direct-action initiatives reflect economic, environmental as well as socio-political transformative capacity at the local level, alternative to the mainstream/dominant capitalist economy;less often they adopt a critical collective resilience stand, and a social movement perspective.

Our AOA findings support the sparse recent works on the impact of crisis on environmental activism, but also document its relation to non-environmentally oriented AAOs. They offer systematic evidence on the durability of bottom-up environmental solidarity action of mutual-support oriented initiatives at the community level, even at times of economic crisis. The fact that slightly more than one third of AAOs that have been active at times of economic crisis in nine examined countries could be labelled as environmental AAOs, suggests that environmental protection or sustainable development is not neglected

even at times of economic hardships. Instead, they provide an opportunity to broaden the scope of action for existing organizations that can adopt sustainability activities focusing on alternative practices and lifestyles. In the long-term these will benefit collective resilience during other crisis periods, not only economic ones. The fact that cross-national variations of EAAO activism did not follow any known patterns, such as being hit hardest by the economic crisis nor opportunities for mobilization of environmental movements, suggests that the trend of developing AAOs in general and EAAOs in particular might be something more universal. Our data does not allow to test the argument, but future studies could examine how much the present EAAOs have been active towards mitigating the consequences of the emerging climate crisis and the health crisis related to the outbreak of COVID-19.

Supporting works attesting the important contribution of community based and alternative solidarity environmental activism, our findings illustrate that EAAOs tend to be informal, but also, to an extent, focused on contention and protests, more than non-environmental ones. By combining their bottom-up solidarity, direct actions focusing on constituency groups, such as environmentally aware citizen-consumers, youth, local communities, small enterprises, with protest activism, EAAOs could create a stronger basis for future environmental activism. The fact that many young people involved in the recent climate strikes did not have the background in traditional environmental organizations but at the same time experienced life-style activism [11] also demonstrates the political potential of the EAAOs examined in our study.

Based on AOA, a new method using online-hub websites, and supplementing them with independent AO websites, we were able to select random samples from extended pools of organizational websites in nine countries, based on a common set of criteria. Our representative findings therefore provide evidence for the significance of direct solidarity actions and its importance for collective resilience and subsequently offer support to related works. More importantly, our findings also bring to surface a different set of environmental concerns and actions, mostly at the community level, across a variety of European settings, unveiling new paths through which citizen initiatives address the multiple challenges faced by 21st century communities.

More in-depth, supplementary analysis could assist in the future through in-depth interviews with purposive samples of (non) EAAO representatives. Such studies could further examine the reasons and the ways in which decisions were made on choosing these paths and the challenges they have been facing.

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Telluric and Climate-Related Risk Awareness, and Risk Mitigation Strategies in the Azores Archipelago: First Steps for Building Societal Resilience

Ante Ivčević [1,2,*], Isabel Estrela Rego [3], Rui Gaspar [4] and Vania Statzu [5]

[1] LPED, IRD, AixMarseille Université, 13331 Marseille, France
[2] UN Environment Programme/Mediterranean Action Plan, Priority Actions Programme/ Regional Activity Centre, HR-21000 Split, Croatia
[3] Research Institute for Volcanology and Risk Assessment, University of the Azores, 9500-321 Ponta Delgada, Portugal; isabel.mc.rego@uac.pt
[4] Católica Research Centre for Psychological-Family and Social Wellbeing, Faculty of Human Sciences, Universidade Católica Portuguesa, 1649-023 Lisbon, Portugal; rgaspar@ucp.pt
[5] Mediterranean Sea and Coast Foundation, 09123 Cagliari, Italy; vaniastatzu@medseafoundation.org
* Correspondence: ante.ivcevic@univ-amu.fr; Tel.: +385-95-878-68-41

Abstract: Islands are often considered excellent socio-ecological laboratories for testing the rapidity of global change since they experience the climate effects of sea-level rise faster than other areas. The Azores are a Portuguese volcanic archipelago located on the junction of the three tectonic plates: the Eurasian, the African and the North American plates. São Miguel, the main island of the Azores archipelago, hosts three active volcanoes, but the last significant volcanic eruption was the Capelinhos volcano on the island of Faial in 1957. Hence, the Azores offers the opportunity to assess insular risk awareness, facing both telluric and climate-related hazards. The key research question emerges from their natural situation: how does the local population perceive the threat of the natural hazards that occur in Azores? Because risks are socially constructed and depend on the uniqueness of territories, risk mitigation strategies must focus on the individual experiences of local dwellers, as a relationship between risk awareness and such strategies may be expected. To analyze this relationship, a web-based survey with a questionnaire including these variables was administered to a sample of Azoreans. The study aimed to assess risk awareness of the Azorean population and find a relationship between this and reported mitigation strategies. The results gave a preliminary insight into Azorean risk awareness of natural hazards and showed a significant positive relationship between risk awareness-raising activities and reported mitigation strategies. This is relevant information for municipalities and regional governments of areas with similar risk exposures, showing that, although risk awareness alone is not enough for measures to be implemented, it may be an important motivational first step for this to occur.

Keywords: telluric risks; climate-related risks; risk awareness; risk management; volcanic islands

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1. Introduction

Portugal is exposed to many natural hazards due to its physical location on the Atlantic Ocean and the natural characteristics of the territory. It comprises the mainland and two volcanic archipelagos, Madeira and Azores, the latter being located on the junction of three tectonic plates: the Eurasian, the African and the North American plates [1,2] (Figure 1).

A huge historical event hit the country's coasts when they suffered a tsunami resulting from an earthquake of magnitude 8.5+, the Lisbon earthquake in 1 November 1755. More recently, the last significant volcanic eruption of the Capelinhos volcano on the island of Faial, Azores, occurred in 1957. Located at the transition between a sub-tropical and an ocean climate, Portugal is also prone to drought periods and flash floods, heatwaves and wildfires, as evidenced by two devastating rural fires that occurred in central Portugal

in June and again in October 2017. The Azores have active volcanoes, such as the Sete Cidades, Fogo and Furnas on the biggest island of São Miguel (Figure 2), but these are sometimes considered to be extinct [3] by the general population, due to a lack of hazard knowledge, low volcanic risk awareness and low preparedness levels [2].

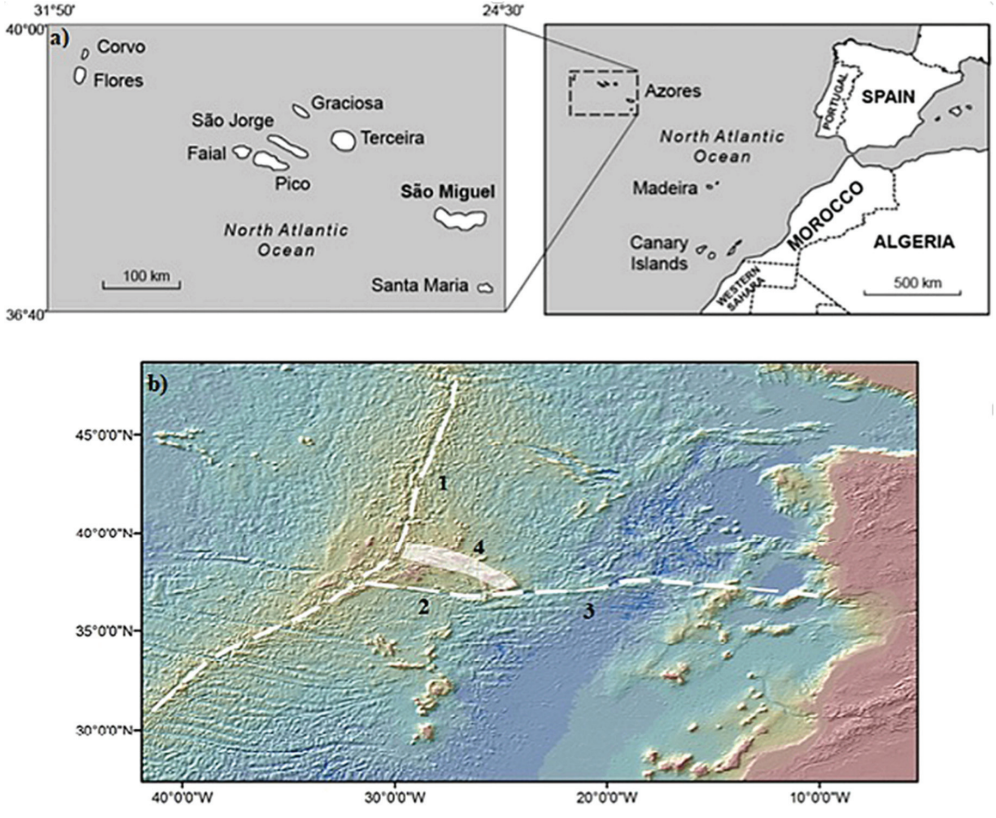

Figure 1. (**a**) Map of the Azores; (**b**) 1 Mid-Atlantic Ridge, 2 Azores-Gibraltar Fracture Zone, 3 Gloria Fault, 4 Terceira Rift. Reprinted from [2].

Understanding risk perception, and particularly risk awareness, is of major importance in risk management. It can improve efficient risk communication and inform mitigation strategies to reduce vulnerability and enhance resilience [1,2,4,5]. In light of the accelerating climate change processes, a better understanding of the role that risk perception has in shaping adaptive behavior is needed in order to cope with extreme weather events and enhance societal resilience [5]. Furthermore, not only local risk perception but also public participation is needed when implementing mitigation measures. This is particularly the case in coastal zones that concentrate population and industrial activities, and even more on small islands, such as the nine islands of the Azorean archipelago [6]. Public experience, perceptions and preparedness and the links between those components contribute to a complex process of risk management [7], the ultimate goal of which is to decrease societal vulnerability and to promote resilience.

Figure 2. Major active volcanoes on the São Miguel Island: **1** Sete Cidades, **2** Fogo, **3** Furnas.

Mitigation strategies are determined by risk perception and the evaluation of the possibility of handling this threat or coping with it [8,9]. Risk perception relates to subjective judgements of risks by individuals in the general population, and it could be described as a 'conceptual understanding' of threat; differently, risk awareness could relate to information and knowledge [10–13]. The concept of risk perception makes the process of risk appropriation multifaceted, since it proposes different logics in perceiving risks for laypeople and experts [14]. Images of risk are, every now and then, distorted. People who have had a previous hazard experience usually display a higher risk perception [15], and those who perceive higher risk are more likely to support governmental plans and take some precautionary measures [16]. However, high-risk perception and awareness do not always generate precautionary behavior [17]. For example, high seismic risk awareness did not result in concrete behavior in a comparative study between the USA, Japan and Turkey [18]. In Costa Rica, the impact of risk perception on risk awareness was detected regarding climate change and floods, but that did not result in more disaster risk reduction measures being adopted [19]. Sometimes a hazard could be considered as very serious, but people still do not to engage in precautionary behavior, as was found in the French Caribbean Island [9] and North Morocco [10]. This is also the case in the Azores, whose population, although vulnerable, appears to be poorly prepared for earthquakes [2]. Similarly, the citizens' perceptions and appraisals about extreme weather events are key for understanding climate change mitigation and adaptation of the population, since climate change creates such new challenges worldwide that it is seen as one of the major societal existential risks [5]. This scientific knowledge and its local appropriation for risk preparedness, and the differences between them, have been found to contribute to the vulnerability of local populations to natural hazards [20,21].

Based on the mechanisms related to risk mitigation strategies, and on the natural situation of the Azores archipelago, key research questions emerge that relate to: how does the local population perceives the threat of the natural hazards and climate change that occur in the Azores? Besides, does their risk awareness relate to them taking precautionary measures, and which mitigation strategies do they report taking? Risks are socially constructed and depend on the physical and cultural uniqueness of territories and must focus on the individual experiences of local dwellers [10]. The socially shared knowledge about their own territory and the local appropriation of natural hazards are of utmost importance for the citizens' preparedness for future changes. Natural hazards, such as telluric and climate related, have occurred throughout history and it is important

to examine how the local Azorean population perceives such hazards. Considering both telluric and climate-related hazards on the Azores islands, has risk awareness concerning the occurrence of natural phenomena in general, and specifically climate change, emerged among the local population? Since the island systems are excellent socio-ecological laboratories for experiments on the rapidity of global change [22,23], they are in a unique context for answering this question. Lastly, this article aims to assess the risk awareness of the Azorean population and to find a relationship between risk awareness and reported mitigation strategies, which can provide the first steps for reducing vulnerabilities and building societal resilience in the Azores.

2. Materials and Methods

2.1. Participants

A convenience sample of 201 individuals was collected, with a minimum age of 18 years old, all of them residents in the Azores archipelago. This sample was collected from an estimated 242,497 total population in 2020 (Available online: https://srea.azores.gov.pt/ReportServer/Pages/ReportViewer.aspx?%2FDemografia%2FEstimativas+da+Popula%C3%A7%C3%A3o+M%C3%A9dia&rs:Command=Render, accessed on 26 July 2020).

The spatial distribution of the sample covered seven of the nine Azorean islands; zero answers were received from the islands of Corvo and São Jorge. Participants' ages ranged from 18 to 75 years, with a mean age of 35.48 (SD = 14.18). Among the participants, 122 were women (60.7%). The sample was mostly well educated, with 33.8% of respondents without any university degree and with 23.4% of respondents having finished post-graduate studies (Master's or PhD degree). One hundred and six respondents (52.7%) were employed, and 54 respondents (26.9%) were students. Only 19 respondents (9.5%) did not work in tertiary activities, among which the main sector was education (35 respondents, 17.4%). The large majority of the sample lived in a household of a size between two to four (165 respondents, 82.1%). Seventy-three respondents (36.3%) were living with children in their household, among which 38 respondents (18.9%) lived and took care of younger children in their families. The majority resided in suburbs or residential, recently constructed areas (131 respondents, 65.1%). Lastly, the participants were asked an income question and only two did not respond to it. The annual net income of families from the sample was mainly between 15.000 and 30.000€ (37.8%), followed by the lower income (24.9%) and by the income between of 30.000 and 45.000€ (22.9%).

2.2. Instrument

Before starting, respondents were introduced to the main study objectives, and their rights in terms of data protection and ethical aspects. Based on this, their consent to participate was requested. A series of questions regarding extreme natural phenomena followed, with a set of 38 questions divided into four sections. The first part considered natural phenomena and measures of precautions. Natural phenomena questioned were: drought, flood, landslides, coastal storms, coastal erosion, sea-level rise, earthquakes, tsunamis, volcanoes, wildfires, heatwaves, and climate change. The second part dealt with risk information, place attachment and social trust. The third part of the questionnaire was dedicated to climate change and measures to address it. Finally, a section with socio-demographic questions followed. The types of questions asked were mainly close-ended (dichotomous and with a Likert 5-point rating scale), with few open-ended questions.

Risk awareness and perception were tested using question items with regards to:

(a) risk perception focused on the likelihood of the future occurrence of natural phenomena in their municipality on a 5-point Likert scale ranging from 1 (highly unlikely to occur) to 5 (it will definitely occur), for each of the ten phenomena in question [12,24];

(b) risk perception focused on how negative the consequences could be if some of the natural phenomena occur, on a 5-point Likert scale ranging from 1 (extremely negative) to 5 (not at all negative), for each of the phenomena [13,25];

(c) self-assessment of how well informed they felt about each of the natural phenomena on a 5-point Likert scale ranging from 1 (not at all informed) to 5 (completely informed) [11,26];

(d) personal experience they had with each of the phenomena (yes/no question), which could be decisive when deciding future protective measures [27], being related [28,29] or not [30] to future behavior;

(e) perceptions of climate change, through a series of questions on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), since recently climate change has been considered an existential security risk and a threat to human civilization [31,32];

Mitigation strategies proposed to participants for their assessment were:

(a) precautionary measures adopted, emergency and awareness-raising activities attended with regards to natural phenomena, on a 5-point Likert scale ranging from 1 (never, none) to 5 (always) [33,34].

(b) indirectly monetary: personal solutions they were ready to adopt in the face of extreme natural phenomena, on a 5-point Likert scale ranging from 1 (nothing) to 5 (completely) [11,13];

(c) directly monetary: preference regarding investment, when imagining that the European Union was promoting a policy to fight climate change in the coming years, they had to choose one out of six options proposed for their personal protection; and willingness to pay to insure their home against calamities resulting from climate change [11,35].

Additional questions related to variables that could have a role in the risk mitigation process:

(a) source of information: different sources the respondents use to inform themselves about extreme national phenomena, on a 5-point Likert scale ranging from 1 (not important) to 5 (totally important) [13,36];

(b) social trust: trust in each of several elements that help to reduce or avoid major damage resulting from natural phenomena and that are therefore useful in management [37,38], on a 5-point Likert scale ranging from 1 (not at all) to 5 (completely);

(c) place attachment: emotional connection that motivates a resident to maintain a relationship with a particular place [39,40], on a 5-point Likert scale ranging from 1 (totally disagree) to 5 (totally agree);

(d) environmental identity: to control the degree to which the respondents identify the importance of their environment and their environmental concerns [10,41], on a 5-point Likert scale ranging from 1 (totally disagree) to 5 (totally agree).

(e) demographic and socio-economic information: various questions on gender, age, education, profession, family composition, housing, and income.

Finally, the readers should note that not all questions from the questionnaire were analyzed for the purpose of this paper. The main questions in this analysis related to risk perception for each of the ten proposed phenomena (future occurrence, severity of consequences and information self-assessment), to awareness of the climate change phenomenon, and to precautionary measures and mitigation strategies. The full questionnaire in Portuguese is available upon request to the authors.

2.3. Data and Procedure

The data were collected online, using the Qualtrics Survey Software. This approach was chosen due to the budget and time constraints of the study, although this excludes the population with no Internet access or digital skills. The data were collected in two four-week periods. One occurred between the end of October and the beginning of November 2020, and another in April 2021, due to the weak initial response. The time needed to complete the survey was close to 30 min. This preliminary survey targeted a broad general population and a convenience sample was obtained through snowball sampling techniques. This means that the final sample cannot be considered representative of the region. Nevertheless, convenience sampling is considered well-suited for exploratory, pilot studies regarding risk awareness [2,42]. The data were analyzed using SPSS software (Version 22.0).

3. Results

3.1. Risk Awareness of Natural Hazards

Participants rated the likelihood of the future occurrence of natural phenomena in their municipality as follows (Figure 3): On average, respondents considered earthquakes (M = 4.34, SD = 0.886) and climate change (M = 4.27, SD = 0.805) as the most likely natural phenomena to occur in their municipality. The least expected phenomena were wildfires (M = 2.17, SD = 1.054), droughts (M = 2.64, SD = 1.184) and tsunamis (M = 2.64, SD = 1.078). Two phenomena whose occurrence was perceived as mostly unknown were volcanic eruptions (M = 3.30, SD = 1.150) and heatwaves (M = 3.00, SD = 1.070). Among the phenomena that the respondents had mostly experienced personally were the earthquakes (29.9%), the coastal storms (25.4%), landslides (16.4%), floods (14.9%); and the least experienced were sea-level rise (3.5%), wildfire (3%), drought and volcanic eruption (1.5% each) and tsunami (zero experience). In total, 101 participants (50.2%) had personally experienced an extreme natural phenomenon, whereas 100 participants (49.8%) from the sample reported no personal experience.

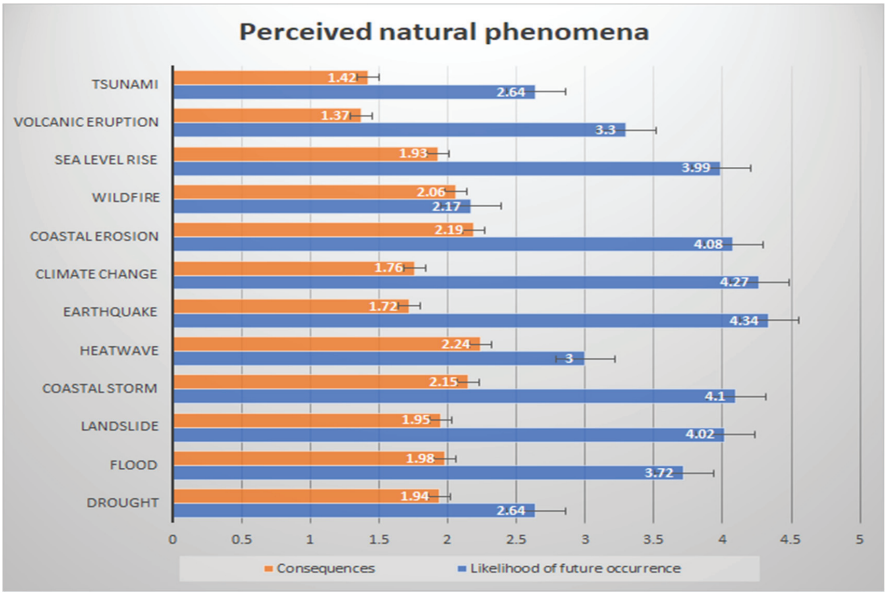

Figure 3. Perceived negative consequences and likelihood of future occurrence of natural phenomena in the Azores.

Furthermore, respondents rated the consequences of some of the natural phenomena occurring (Figure 3). The most severe consequences were assigned to volcanic eruptions (M = 1.37, SD = 0.703) and to tsunamis (M = 1.42, SD = 0.689), and the least severe wereconsidered to be heatwaves (M = 2.24, SD = 0.930), coastal erosion (M = 2.19, SD = 0.891), and coastal storms (M = 2.15, SD = 0.904), although the least severe can still be considered to have very negative consequences.

Finally, the respondents self-assessed their level of information about each of the natural phenomena. On average, they felt informed regarding all the phenomena, feeling the least informed about heatwaves (M = 2.94, SD = 0.960), and the most informed about volcanic eruptions (M = 3.44, SD = 1.099). As sources of information on extreme natural phenomena, the respondents appreciated the Civil Protection Agency the most (M = 4.65, SD = 0.639) and social networks the least (M = 3.57, SD = 1.143). Similarly, respondents expressed the highest trust in scientists (M = 4.33, SD = 0.736) and in the Civil Protection

Agency and similar public institutions involved in managing extreme natural phenomena (M = 4.28, SD = 0.744) to reduce or avoid major damage, and the least trust in social networks (M = 3.16, SD = 1.004).

3.2. Climate Change Perceptions

Respondents seemed to be quite aware of the reality of climate change. As mentioned previously, respondents considered climate change (M = 4.27, SD = 0.805) to be the second most likely natural phenomena to occur in their municipality in the future. They also felt second-best informed about climate change (M = 3.63, SD = 0.851).

In addition, the participants expressed their opinion on climate change through a series of questions. They had often heard talk about climate change (M = 4.33, SD = 0.776). They did believe that human beings with their activities had a great responsibility in relation to climate change (M = 4.50, SD = 0.775). They were also worried about the future of many animals and plants living in the seas and coastal areas and believed that they would become extinct due to climate change (M = 4.25, SD = 0.823). The participants only seemed to be a bit confused about the temporal distance of climate change consequences. They agreed that they were already experiencing the effects of climate change in the Azores (M = 4.02, SD = 0.774), but were less certain about whether the effects of climate change in the Azores would occur in the next 25 years (M = 3.47, SD = 1.105).

3.3. Reported Precautionary Measures and Mitigation Strategies

When asked about measures adopted against natural phenomena, the participants reported to having rarely implemented such precautionary behavior. They somewhat reported having taken measures (e.g., use of more resistant building materials, home automation systems, lightning rods, other technologies) to avoid damage from a possible natural phenomenon rarely that is, a few times (M = 2.67, SD = 1.214). They also somewhat reported having participated in courses on emergency, safety, fire prevention, and so forth, or adopted behaviors to avoid the damage that could result from a possible natural phenomenon (M = 2.49, SD = 1.110), and reported having rarely participated in information and awareness-raising activities concerning natural phenomena (M = 2.57, SD = 1.121).

Moreover, the participants' readiness to adopt personal solutions to face extreme natural phenomena was mixed. They were very eager to reduce the amount of waste produced and to recycle every day (M = 4.37, SD = 0.857), were somewhat ready to eat more organic food and less meat (M = 3.32, SD = 1.162) and to use public transport more often (M = 2.97, SD = 1.233), and little ready to move to another region (M = 1.75, SD = 1.063). These actions corresponded to their reported place attachment: the participants were proud to live in their municipality (M = 3.91, SD = 0.887), and they would regret it if they had to move to another municipality (M = 3.75, SD = 1.094); and as for their environmental identity, they considered themselves people who cared about the environment (M = 4.31, SD = 0.644), but they considered themselves less involved in environmental activities in their municipalities (M = 2.83, SD = 1.087).

Correlations between the risk awareness items (measures taken, course participation, and awareness activities) and the mitigation strategies items (recycling, public transport, organic food, move out) were examined, to assess whether or not there was a significant positive relationship between awareness and reported strategies. Among the correlations, presented in Table 1, participating in courses was both positively correlated with taking measures and with participating in awareness-raising activities. However, only the latter shows significant and positive correlations with mitigation strategies: with using public transport more often (0.154, $p < 0.05$) and with eating more organic food and less meat (0.184, $p < 0.01$).

Table 1. Correlations between risk awareness items and mitigation strategies items.

	Measures Taken	Course Participation	Awareness Activities	Recycling	Public Transport	Organic Food	Move Out
Measures taken		0.215 **	0.082	0.082	0.010	–0.083	0.054
Course participation			0.564 **	0.111	0.128	0.105	0.085
Awareness activities				0.073	0.154 *	0.184 *	–0.012
Recycling					0.228 **	0.280 **	–0.148 *
Public transport						0.342 **	0.059
Organic food							0.055
Move out							

** with significance < 0.01. * with significance < 0.05.

Finally, the participants expressed their preference regarding investment, when imagining the European Union's policy to fight climate change. Fourteen respondents (7%) would prefer to move to a safer place and 19 respondents (9.5%) would choose none: they would be satisfied with public compensation, even if reduced. Four respondents (2%) would choose insurance when taking out a mortgage to purchase a property. A more popular preference was to invest in infrastructures that better protected the respondent and her property, chosen 34 times (16.9%). The second most popular option was to choose insurance that protects the participant's assets and family, assessing the best option on the market, elected 61 times (30.3%). Finally, 69 respondents (34.3%) considered that, since climate change was caused by everyone's behavior, there should be compulsory insurance for everyone. More precisely, when asked for the highest amount they would be willing to spend per year to insure their home against calamities resulting from climate change, 193 respondents answered and expressed a willingness to pay of median value of 150€ (preferred over mean value due to outliers and skewed data for a range of values between 0 and 20,000€).

4. Discussion

The local population in the Azores is seemingly aware of telluric hazards, namely the threats that earthquakes pose to their lives, with the same occurring for climate change related hazards. Respondents considered earthquakes and climate change related events to be the most likely natural phenomena to occur in their municipality. The former was expected because it is the most personally experienced hazard in the archipelago. The latter, although less experienced, is also something that the population is aware of. Volcanic eruptions, however, are the phenomenon they most felt informed about and with the most severe consequences expected, while also being perceived to be among the phenomena whose occurrence is the most unknown. This perceived severity of a volcanic eruption opposes previous findings [1,3]. The participants mostly reported using the Civil Protection Agency as the source of information about natural phenomena, with the least reported source used being their social networks. They also expressed the highest trust in scientists and the Civil Protection Agency. Results indicate that the perception of occurrence is based on their experience and general knowledge about seismic hazards and the location of the archipelago, which is the case for the earthquakes. However, this perception is seemingly missing for volcanic eruptions. Similar conclusions are brought out in a study [2] regarding the São Miguel island.

All these results mean the local population is highly risk aware. The results also indicate that there is a relationship between risk awareness and reported mitigation strategies. Participating in awareness-raising activities showed significant and positive correlation with the reported mitigation strategies of using public transport more often and with eating more organic food and less meat. However, although risk awareness has been shown in many studies as not being enough to implement risk mitigation strategies (as is demonstrated by the low levels of mitigation measures reported), it remains an important first step to do so and for ultimately building societal resilience, as discussed in [4]. The question that is posed is how to reduce the gap between having hazard knowledge and

using this knowledge to implement precautionary behaviors? Could it be related to their low perceived control and self-efficacy as they are somewhat unable to overcome (structural and socio-psychological) barriers to mitigation strategies behaviors' implementation [43], associated with the geological history and nature of the archipelago? Further research should focus on such barriers and test possible differences in perception regarding two different groups of hazards, telluric and climate-related, and how this difference can be explained. The place for testing and addressing this issue could be the Azores, since both groups of hazards co-occur in this location and since islands in general are praised as "living labs" for studying the rapidity of global change [22].

Answers regarding insurance and policy preferences indicate that it would be interesting to estimate how much the respondents are willing to pay to protect their house against risks related to climate change using more precise methods than just expressing the maximum annual insurance, such as contingent valuation exercises. The willingness of the local population to invest and protect against hazards should be tested in a more robust way than that presented here, as exemplified in a Sardinian study [11], due to a lack of analysis on climate change and hazard insurance adoption at regional, national and global levels. In addition, societal resilience could be enhanced by using an analytical method that helps to interpret strengths and weaknesses to identify opportunities and threats of a system (SWOT analysis), as showcased in recent European examples [44,45].

These elements could provide useful information to decision-makers in charge of risk management and climate change mitigation measures. Improved dialogue and participatory approaches between scientists, managers' and civil society need to be enhanced. Societal risks could be tackled by an improved dialogue, collaboration, and engagement in shared activities, based on scientific and local knowledge and through the institutional and social adaptations resulting from them. The dire need to address the physical phenomena of hazards as well as how they are socially constructed, is an urgent current need. This interdisciplinary path empowers different cultural, economic, and demographic contexts with a participatory approach in the process of building societal resilience.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

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Article

Multi-Risk Assessment and Management—A Comparative Study of the Current State of Affairs in Chile and Ecuador

Stefan Greiving [1,2,*], Leonie Schödl [2], Karl-Heinz Gaudry [3,4], Iris Katherine Quintana Miralles [5], Benjamín Prado Larraín [6], Mark Fleischhauer [1,2], Myriam Margoth Jácome Guerra [7] and Jonathan Tobar [3]

1 Institut für Raumplanung (IRPUD), TU Dortmund University, 44227 Dortmund, Germany; mark.fleischhauer@tu-dortmund.de
2 Plan + Risk Consult, 44227 Dortmund, Germany; schoedl@plan-risk-consult.de
3 Instituto de Investigación Geológico y Energético (IIGE), Quito 170518, Ecuador; karl.gaudry@geoenergia.gob.ec or karl.gaudry@cimonline.de (K.-H.G.); jonathan.tobar@geoenergia.gob.ec (J.T.)
4 Centre for International Migration and Development (GIZ/CIM), 65760 Eschborn, Germany
5 Independent Researcher, Lima 15000, Peru; iquintanamiralles@gmail.com
6 Independent Researcher, Santiago 92101, Chile; benjamin.pradolarrain@gmail.com
7 Institute for Housing and Urban Development Studies (IHS), Erasmus University Rotterdam, 3062 PA Rotterdam, The Netherlands; myryamjc10@gmail.com
* Correspondence: stefan.greiving@tu-dortmund.de

Abstract: In Chile and Ecuador, multiple hazards and dynamic processes in vulnerability pose a high risk. Spatial planning and emergency management can contribute to disaster risk management but they follow different goals. However, global goals, such as from UN-ISDR (United Nations International Strategy for Disaster Risk Reduction) and UN SDGs (Sustainable Development Goals) can potentially support cities and regions in defining concerted action. This paper aims at measuring the performance of Chile and Ecuador in regard to the aforementioned policy goals. Although both countries show considerable progresses in the implementation of the UN strategies, it is doubtful that the existing global monitoring approach is appropriately designed for measuring the real situation on the ground. Our paper is based on a desktop research combined with stakeholder workshops and expert interviews. Overall, both countries made considerable progress in regard to disaster preparedness and monitoring. However, multi-risks are rarely considered and there is still increasing vulnerability due to the expansion of informal settlements. The risk management is characterized by an imbalanced distribution of financial resources and institutional capacities between the metropolitan regions and smaller municipalities, and by low public participation and hardly community-based approaches. The paper underlines the importance for more qualitative, in-depth studies on the root causes of disaster risk which could complement the global monitoring which is very much focused on quantitative data and shows inconsistency between input and output indicators.

Keywords: disaster risk; vulnerability; monitoring; risk assessment; disaster management; UN-ISDR; SDGs

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1. Introduction

Worldwide, disaster risk and climate change are emerging topics, which are, in the Global South, deeply intertwined with rapid urbanization processes and population growth, which applies also to the Latin American Countries of Chile and Ecuador that are the focus of this paper. Disaster risks are seriously determined by the vulnerability of an exposed place.

Coping with these threats is one of the key objectives of the global policy agenda, manifested by the seven global targets of the Sendai Framework for Disaster Risk Reduction [1] and the 17 Sustainable Development Goals (SDGs), adopted by all UN Member States in

2015, as part of the 2030 Agenda for Sustainable Development which set out a 15-year plan to achieve these goals [2].

A set of 38 indicators [3] was identified by UN-ISDR (United Nations International Strategy for Disaster Risk Reduction) to measure the global progress in the implementation of the Sendai Framework for Disaster Risk Reduction. The indicators measure progress in achieving the global targets of the Sendai Framework, and determine global trends in the reduction of risk and losses [3].

In principle, there are a couple of explicit relationships between several targets of the SDGs and the Sendai Framework, namely SDGs 1, 11 and 13: eradication of poverty, resilient and sustainable cities, and action to climate change, as shown by Figure 1. For these communalities, a joint monitoring scheme has been adopted by the UN.

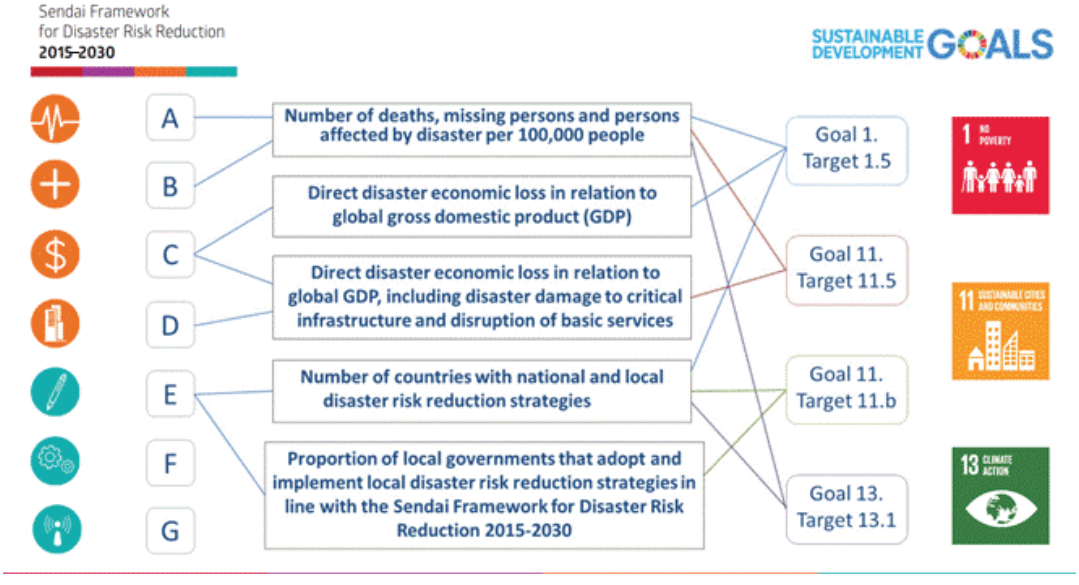

Figure 1. Sendai Framework and the 2030 Agenda [4].

For this purpose, the UN-ISDR publishes every year a so-called "Global Assessment Report" on global and national level key achievements in regard to these 38 indicators [5]. Data reported by Member States against the global plan to reduce disaster risk and losses is publicly available [6]. However, only few UN Member States have fulfilled their full reporting requirements and 79 started to enter global target's data. Here, Chile's national platform is a positive example. The country already came up with its 2019 report [7]. A similar platform does not exist in Ecuador yet.

However, the aforementioned 38 indicators are identified to measure the progress in achieving the global targets of the Sendai Framework and related SDGs, and determine global trends in the reduction of risk and losses. The indicators reflect the seven global targets shown by Figure 1. The global targets A–D are clearly output-oriented:

- Global target A: "Substantially reduce global disaster mortality by 2030, aiming to lower average per 100,000 global mortality between 2020–2030 compared with 2005–2015."
- Global target B: "Substantially reduce the number of affected people globally by 2030, aiming to lower the average global figure per 100,000 between 2020–2030 compared with 2005–2015."
- Global target C: "Reduce direct disaster economic loss in relation to global gross domestic product (GDP) by 2030."

- Global target D: "Substantially reduce disaster damage to critical infrastructure and disruption of basic services, among them health and educational facilities, including through developing their resilience by 2030."

On the contrary, the global targets E–G and related indicators aim at inputs which are supportive to achieve the desired outputs of the Sendai Framework:

- Global target E: "Substantially increase the number of countries with national and local disaster risk reduction strategies by 2020."
- Global target F: "Substantially enhance international cooperation to developing countries through adequate and sustainable support to complement their national actions for implementation of this framework by 2030."
- Global target G: "Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to the people by 2030."

This paper aims at improving the validity of the global monitoring approach which is in its current design inappropriate to identify the root causes of vulnerability and risk, but also factors for success and failure in regard to the output targets A–D. We want to derive lessons learned out of a comparative analysis between the two Latin American countries, Chile and Ecuador, which can be used for assessing and ultimately improving the performance of the current global monitoring approach. For this purpose, an in-depth look at specific contexts and their governance arrangements is required. These two countries share a similar risk profile (they are part of the Pacific Ring of Fire), but differ considerably in regard to disaster risk management and are, at the same time, rarely addressed by international literature (in particular Ecuador). Specific attention is spent on the largest metropolitan regions of Quito and Santiago de Chile due to their hazard profile and considerable vulnerability as economic powerhouses of their countries, but also their outstanding disaster risk management capacities [7]. The paper is guided by the following research questions:

- What are the root causes of vulnerability and risk in Chile and Ecuador?
- How do these two Latin American countries perform in regard to the aforementioned global output targets E and G?

2. State of the Art in Multi-Risk Assessment and Management

Concepts for assessing risk from a spatial perspective were first developed by geographers in the 1970s [8]. This was first dominated by a focus on mapping hazards ('hazards of place') and risks. However, as Cutter [8] noted, further methodological elaborations on this subject have only rarely been attempted until the mid-1990s. It is due to authors like Burby [9] or Godschalk et al. [10] that the important role of land-use planning, and how it plays in the whole disaster management cycle, was highlighted. The other important contributor to risk management strategies is the emergency management. Its role is expressed by the capacity to cope with an extreme event. However, the actions of these two spheres are in many cases separated from each other and are characterized by a lack of common objectives and strategies [11,12]. Nonetheless, both actors—being responsible for managing the land-use of a certain area and protecting an area against any kind of threat—share the understanding that disaster risk management requires a multi-risk perspective [13,14]. This calls for a multi-risk assessment which "determine the total risk from several hazards either occurring at the same time or shortly following each other, because they are dependent from one another or because they are caused by the same triggering event or hazard; or merely threatening the same elements at risk (vulnerable/exposed elements) without chronological coincidence" [15]. Multi-risk is also an issue in the Sendai Framework for Disaster Risk Reduction, which propagates disaster risk reduction practices "to be multi-hazard and multi-sectoral, inclusive and accessible in order to be efficient and effective" [1] (p. 10).

Opposite to the well-established assessment of single hazards and risks, this kind of assessment looks at the interdependencies of the occurring hazards and requires a consideration of cascading effects, even outside the exposed area. Coinciding hazards can result in cumulative and cascading effects meaning that one hazard can follow up with subsequent hazards with bigger impacts and, in total, accumulate negative effects. However, multi-risk perspectives are not systematically addressed among disaster risk management approaches and single-hazard maps are still the decision support tool most often used [16]. A multi-risk management calls for decisions in land-use planning on tolerating or altering these interactions and selecting appropriate mitigation measures. Assessing multi-risk is rather complex and still remains a challenge. A detailed multi-risk assessment is connected to the difficulty of quantifying all kinds of scenarios and working with a large data amount meaning that technical standards are required and needed data are made available. Challenges of assessing multi-risks occur because of the interdependencies of sectors and related communication channels, and require multi-risk governance [17].

There is also an ongoing discussion on transformative resilience focusing on a system's capacity to adapt or transform in the face of emerging multi-risks to support sustainability [18,19]. For its application in the practice of disaster management and urban sustainability, building resilience for reducing vulnerability needs flexibility, learning and change [20] as well as a participatory and inclusive approach allowing vulnerable individuals and groups to play an active role in determining how best to avoid hazards and build capacity and, ultimately, just cities [21]. These theoretical discussions on sustainability and resilience clearly underline the importance of community-based strategies which are tailor-made to specific legal and cultural contexts.

3. Methods

Since our paper aims at a better understanding of the causing factors of the given performance of the two countries Chile and Ecuador in regard to the global output targets A–D, we focus on the input targets E and G and related indicators which address the national as well as local levels (that is why target F on international cooperation is not addressed by our study).

The national performance regarding these seven input indicators (see below) is to be reported to UN-ISDR annually in quantitative numbers (see the Global Assessment Report 2019 [4]). However, these input indicators neither really explain the root causes of disaster nor do they correlate with the observed disaster impacts addressed by the global output targets A–D. For the understanding of the underlying reasons of why a country fails or succeeds in disaster risk management, a deeper look at the methods, procedures and tools is required which have been used in context of disaster risk assessment and management [22]. Our paper therefore specifies, from within the seven input indicators of the global targets E and G, the following guiding questions (marked in italics):

- E-1: Number of countries that adopt and implement national disaster risk reduction strategies in line with the Sendai Framework for Disaster Risk Reduction (DDR) 2015–2030:
  - *Did Chile and Ecuador adopt national strategies?*
- E-2: Percentage of local governments that adopt and implement local disaster risk reduction strategies in line with national strategies:
  - *Have Chilean and Ecuadorian cities adopted local DRR strategies? Are the output targets A–D addressed by these strategies and if yes, how?*
- G-2: Number of countries that have multi-hazard monitoring and forecasting systems.
  - *Do Chile and Ecuador have such a system in place?*
- G-3: Number of people per 100,000 that are covered by early warning information through local governments or through national dissemination mechanisms.

- *What is the diffusion rate of early warning systems in Chile and Ecuador? For which hazards are these systems established?*

- G-4: Percentage of local governments having a plan to act on early warnings.

- *To what extent do emergency management plans exist at the local level in Chile and Ecuador? Do they include preparedness and response strategies based on early warnings?*

- G-5: Number of countries that have accessible, understandable, usable and relevant disaster risk information and assessment available to the people at the national and local levels.

- *Is this kind of information available in Chile and Ecuador on the national level? Does an evidence basis for multi-risk assessment exist at the local level?*

- G-6: Percentage of population exposed to or at risk from disasters protected through pre-emptive evacuation following early warning.

- *Have evacuations been effectively used in Chile and Ecuador? If yes, for which types of events?*

Data on the performance of both countries were not gathered from the incomplete global UN-ISDR database, but a desk-top analysis of national policy documents and strategies from Chile and Ecuador as well as local risk management and land-use plans from Quito and Santiago de Chile.

Further, primary data for an in-depth evaluation of context-specific assessment and management strategies were collected during a field trip and two workshops in Ecuador. The first one took place on 22 November 2019 in Latacunga with representatives of the provincial departments of spatial planning and emergency management, and the municipality of Latacunga (departments of land-use planning, emergency management, environment, housing and water management). A second workshop was organized in Quito in the evening of the same day with representatives from several governmental agencies (Ministerio de Desarrollo Urbano y Vivienda (MIDUVI, Quito, Ecuador), Secretaria Tecnica Planifica Ecuador (STPE) (former SENPLADES, Quito, Ecuador), Ministerio del Ambiente y Agua (MAE), Servicio Nacional de Gestión de Riesgos y Emergencias (SNGRE) (former SNR), Concejo Nacional de Competencias (CNC), Superintendecia de Ordenamiento Territorial (SOT), Instituto de Investigación Geológico y Energético (IIGE, Quito, Ecuador) and the NGO Grupo Faro, Quito, Ecuador.

The workshop planned for November 2019 in Santiago de Chile had to be cancelled due to the violent political unrest which Chile experienced from October 2019 till early 2020. After that, physical meetings were not possible due to the COVID-19 pandemic.

In addition, we conducted expert interviews with stakeholders from various agencies in order to validate our empirical findings in both countries. In Ecuador, the two interviewees were representatives of the national spatial development authority (Dirección Nacional Técnica y Planificación/Asociación de Municipalidades Ecuatrianas, AME, Quito, Ecuador) and disaster risk management (Asociación de Profesionales de Gestión de Riesgos del Ecuador, APGRE). In Chile, we interviewed one representative from the national emergency office (ONEMI, Santiago, Chile).

4. Case Studies

4.1. Chile

Due to its geographical position in the Pacific Ring of Fire and its latitudinal extension of about 4300 km, Chile is exposed to a great diversity of climates and extreme natural events as earthquakes, volcanic eruptions, droughts, intense rainfall, floods and landslides (see Figure 2). From these, the hydro-meteorological events have become the most frequent in recent years. However, earthquakes and tsunamis have a history of greatest damage, in terms of fatalities and economic impacts [23].

Figure 2. Geophysical map of Chile.

As in the rest of Latin America, Chile has a high level of urbanization with almost 90% [24] of its population living in urban areas. This urbanization, product of a rapid and unplanned growth, occupied hazard prone areas and recreated the unequal and exclusionary shape of Chilean society in the spatial distribution of human settlements [25].

This country has experienced a strong economic growth in the recent decades, but the benefits from this progress have not been equally distributed across society, but rather concentrated in the wealthiest sectors of society [26]. Thus, inequality might be the main vulnerability to risk in Chile; which is so high and deeply rooted, that it can be seen as the core reason of the social outbreak that began in October 2019. Inequality that generates different levels of exposure to risk among the different segments of society affects the poor harder and with longer impacts.

Additionally, the Chilean DRR system is neither comprehensive nor participative. In general, the population is excluded from the planning processes and is only consulted to validate decisions. Despite all this, Chile is a regional leader in terms of its low physical

vulnerability due to the effective and wide implementation of the earthquake resistant building code [27]. Moreover, in recent years, the study and monitoring systems are improving by generating timely and more characterized risk information; and decentralizing and giving strength to the early warning and monitoring systems at regional level [28].

Despite the fact that the cities of Santiago (about 7 million inhabitants) and Valparaíso (1.8 million) integrate several communes, metropolitan administration does not exist in the political-administrative structure of the country. Santiago, as a commune, is the capital of the country and of the "Metropolitana" region. Located in the foothills of Andes mountain range, Greater Santiago is made up of 36 communes and is affected by earthquakes and flooding throughout the entire city, and by landslides and heavy rainfall in certain communes near the mountains. Here, earthquakes have left the most expensive damage [29]. The commune of Valparaiso is the capital of the homonymous region. Greater Valparaiso is made up of 8 communes. Located in a bay surrounded by an amphitheater of hills that descend towards the Pacific Ocean, it has been historically exposed to earthquakes, tsunami, heavy rainfall, landslides and forest fires. Both cities have similarities in terms of urban growth patterns and vulnerabilities, like the occupation of hazard prone areas, deep inequality and segregated poverty that constrains the capacity of the population to own worthy housing. This is reflected in the poor quality of construction in Santiago [30] and large sectors of informal settlements in Valparaíso [31]. It should be noted that by 2018, it was estimated that there were 741 informal settlements (*campamentos*) in Chile, inhabited by 43,000 families. In the Valparaíso Region were 188 informal settlements with 11,150 families, and in the Metropolitan Region were counted 84 informal settlements with 4214 families [32].

Both cities are managed at two levels: locally, by a municipality for each commune that makes up the city, and by the regional government within which each city belongs. In practice, the regional level assumes a comprehensive role for each city in terms of disaster risk reduction, while the local level historically had a prominent role in land-use planning. Regarding land-use, it is expected that each level generates their respective plans for land-use, using the "Guide for the Analysis of Natural Risks for the Land-Use Planning" [33] that includes a disaster risk management (DRM) perspective. For disaster risk reduction, all levels must constitute a Civil Protection Committee, which switches to Emergency Operation Committee during an emergency. These Committees are in charge to develop disaster risk reduction and emergency plans. The generic development of these plans, which lack local-based information, evidences that guidelines emanated from central level are poorly followed by regions and especially communes. Municipalities are weak institutions with low managerial capacity, economic and political power. Again, inequality determines their different access to resources. Communes with less resources and higher vulnerability designate less money per habitant for DRM actions, especially in larger population communes. Budgets are mainly focused on rapid emergency response rather than prevention actions [34].

4.2. Ecuador

Ecuador has four main geographic regions (see Figure 3): La Costa, or "the coast": The coastal region consists of the provinces to the west of the Andean range. It is the country's most fertile and productive land. The largest coastal city is Guayaquil. La Sierra, or "the highlands": The sierra consists of the Andean and Interandean highland provinces. This land contains most of Ecuador's volcanoes. The largest Sierran city is the capital, Quito. La Amazonía, also known as El Oriente: The oriente consists of the Amazon jungle provinces. La Región Insular is the region comprising the Galápagos Islands, about 1000 km west of the mainland in the Pacific Ocean.

The country is highly affected by a number of natural hazards [35]. Due to the subduction of the Nazca Plate under the South American Plate, the region shows a high seismic and volcanic risk. Furthermore, El Niño leads to heavy rainfall as well as draught periods. As a result, Ecuador also faces problems such as landslides in the mountain areas.

Due to the high variety of natural hazards, Ecuador frequently is affected by multi-hazard events, meaning that one hazard can trigger another one, for example, an earthquake followed by landslides or a tsunami [36].

At the same time, many cities in Ecuador are facing high population growth in recent decades and an expansive, widely uncontrolled urban development, which has led to the appropriation of a vast territory with low population density. These areas typically present a high degree of inequality of services, green areas and infrastructure. Many settlements have a high vulnerability to disaster risk because they are located in highly hazardous areas [37]. Especially informal settlements are affected by this problem. As stated by the Subsecretariat of Habitat and Human Settlements [38], 88% of the country's municipalities present some informal settlements. There are approximately 2.9 million people living in 729.291 houses located in informal settlements, which makes up almost 20% of the Ecuadorian population. About two thirds of these settlements are located in urban areas, whereas one third can be found in rural areas.

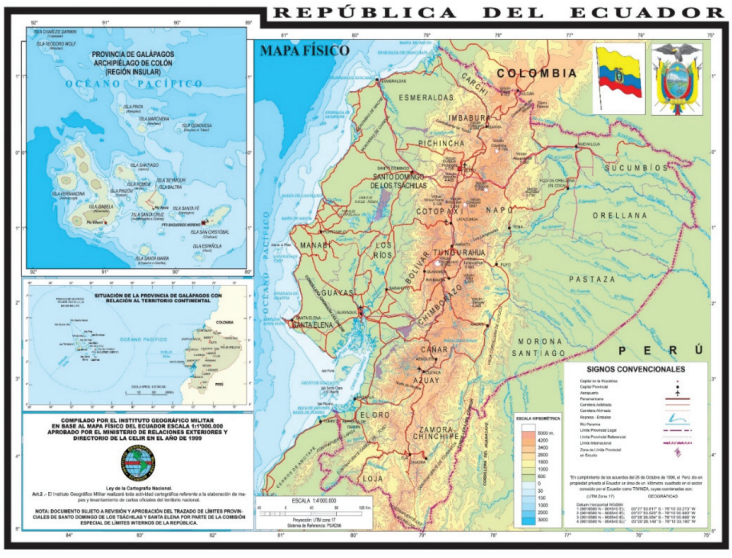

Figure 3. Geophysical map of Ecuador [39].

It was not until 2016 that Ecuador experienced a sequence of events—natural and social—that constituted a milestone in the history of DRR in the country. In September 2020, the College of Architects of Ecuador launched the Geoportal of the Quito Urban Information Centre. This innovative digital tool allows users to access georeferenced data for the entire metropolitan district of Quito, providing access to information on types of soil and mechanical properties (used mainly for hazards modeling), urban growth data, environmental services and relevant information for risk management, such as public and open spaces, immediate aid units, community police stations, medical centers, etc. [40].

Quito, as the capital city (2.8 million inhabitants), is located between the slopes of the Pichincha volcano to the west and a system of active geological faults to the east. As a particular factor, every summer it experiences heavy seasonal rains. Due to its natural condition at being crossed by four tectonic faults and surrounded by 20 volcanoes, the Metropolitan District of Quito (DMQ by its Spanish abbreviation) is exposed to multiple natural and anthropogenic threats that can directly affect the population and infrastructure located in vulnerable sectors [41]. Together, these characteristics produce a combination for multiple hazard events to occur simultaneously, including mass movements, floods, and forest fires, which are the most recurrent phenomena in the territory. However, volcanic

eruptions and earthquakes are other manifestations of natural origin that have occurred on previous occasions and could recur. In addition, Quito is also expanding rapidly, and already by 2018, it became the largest city in Ecuador [42].

In September 2008, the municipality of Quito created the "Metropolitan System of Integral Risk Management of the DMQ and its Components". In July 2016, the municipality of Quito presented the "Quito Ready" Program which includes the axes of "Awareness", "Training", "Prevention" and "Response" to six types of natural and two human-made hazards that occur in the DMQ. In October 2017, the International Meeting "Quito: One Year after Habitat III" was celebrated. By then, the Metropolitan Disaster Risk Reduction Management Plan of Quito "Quito Listo" was presented [43]. Developed by the Quito's "General Secretariat for Security and Governance", the plan, aligned with the Sendai Framework focuses on five areas: (1) Quito understanding risk, (2) A strengthened Quito implements the Plan, (3) Quito reduces vulnerability, (4) Quito protects infrastructure and (5) Quito is prepared for emergencies. In the same year, the Plan for Prevention and Response to Adverse Events in the DMQ (floods and mass movements) was presented by the municipality.

This combination of multi-hazard risk and rapid urbanization implies that urban development inevitably coincides with hazard hotspots, placing intensifying stress on communities, infrastructure and sustainable development. Although the politics of the metropolitan government have exacerbated these risks over the last 30 years, less has been placed on regarding how disaster risk reduction can be integrated into urban development.

5. Results

In the following, we present our empirical results regarding the seven aforementioned global input indicators. Table 1 provides a comprehensive overview about key characteristics of both countries:

Table 1. Key characteristics of Chile and Ecuador.

Issue	Chile	Ecuador
General		
Past disasters	Earthquakes and tsunamis with greatest damage, furthermore, droughts, intense rainfall, floods and landslides	Seismic (earthquake, tsunami), volcanic, heavy rainfall and drought, landslides; multi-hazard events
Population, total	19.0 million (2019)	17.4 million (2019)
Urban population (% of total population)	88% (2019)	64% (2019)
Urban population growth (annual %)	1.27% (2019)	1.93% (2019)
Informal settlements	741 informal settlements, populated by 43,000 families (2018)	88% of municipalities with informal settlements with 2.9 million inhabitants (20% of population)

The following Table 2 sums up the relevant results in regard to the global input indicators E and G:

Indicator E-1. *Did Chile and Ecuador adopt national disaster risk reduction strategies in line with the Sendai Framework for Disaster Risk Reduction 2015–2030?*

In **Chile**, the Sendai Framework for Disaster Risk Reduction was adopted in 2015, in accordance with the 69/283 resolution. The National Emergency Office (ONEMI) has the mandate of monitoring the implementation of the Sendai Framework. For this, it coordinates with the Social Development Minister (in charge of the Agenda 2030 implementation) and the National Institute of Statistics. The three main national tools that guide, implement and promote disaster risk reduction strategies are the National Policy for Disaster Risk Reduction (PNGRD) [44], the National Strategic Plan for Disaster Risk Reduction 2015–2018 (PENGRD) [45] and the National Platform for Disaster Risk Reduction.

Table 2. Similarities and differences between empirical results from Chile and Ecuador [own elaboration based on various sources (see text below)].

Indicator	Chile	Ecuador
Indicator E-1: Did Chile and Ecuador adopt national disaster risk reduction strategies in line with the Sendai Framework for Disaster Risk Reduction 2015–2030?	Adopted national disaster risk reduction strategy. Official version is not in line with the Sendai Framework, but new, already internally used version will be adopted soon.	Adopted national disaster risk reduction strategy. In line with the Sendai Framework.
Indicator E-2: Percentage of local governments that adopt and implement local disaster risk reduction strategies in line with national strategies.	A considerable amount of local governments (about 40%) adopted and implemented local disaster risk reduction strategies. Not linked to Sendai targets.	Exact numbers not available. Not linked to Sendai targets.
Indicator G-2: Do Chile and Ecuador have multi-hazard monitoring and forecasting systems in place?	Extensive hazard monitoring and forecasting systems exist, but only related to various single hazards (managed by various different authorities).	Extensive hazard monitoring and forecasting systems exist, but only related to various single hazards (managed by various different authorities).
Indicator G-3: Number of people per 100,000 that are covered by early warning information through local governments or through national dissemination mechanisms.	25% of the population has a comprehensive early warning center which delivers information through the mobile phone network.	No quantitative information available. Early warning information are delivered for different hazards by various different agencies.
Indicator G-4: Percentage of local governments having a plan to act on early warnings.	68% of municipalities have a Communal Emergency Plan.	18% of all municipalities have a plan to act on the tsunami early warning system (only the regions along the coast). 3–5% of all municipalities have a plan to act on the volcanic early warning system (only the regions exposed to volcanic hazards).
Indicator G-5: Do Chile and Ecuador have accessible, understandable, usable and relevant disaster risk information and assessment available to the people at the national and local levels?	Systematic information is openly available.	Accessible, understandable, usable and relevant information available. Most of the data on threats is not open access.
Indicator G-6: Percentage of population exposed to or at risk from disasters protected through pre-emptive evacuation following early warning.	No quantitative information available.	No quantitative information available.

The publicly available PNGRD was presented in 2014, and approved in 2016. It aligns its main strategic axes and objectives with the main axes of the Hyogo Framework of Action. The PENGRD began its formulation in 2014, aligning to the 26 national policy objectives as well as to the Hyogo Framework respectively. It proposes 84 strategic actions for the period 2015–2018. The PENGRD has not been updated to the Sendai Framework yet.

A new PNGRD, aligned to the Sendai Framework goals, is in use since 2019 among the agencies that integrate the national platform for DRR, and will be in force until 2030. This new policy has not been officialized or promulgated yet. In order to be published, this policy needs to be approved by the General Comptroller of the Republic [46].

On the other hand, the National Platform for Disaster Risk Reduction was formed up in 2012. However, it was not formally constituted with its respective regulation until 2015. The platform is an advisory body of the National Emergency Office (ONEMI), that seeks to establish and promote DRR at all levels. Nonetheless, it changed its regulation in 2018, where under consideration of the Sendai Framework for DRR, sets as one of its specific objectives to "ensure the coherence of international instruments, whatever their

nature, relating and integrating into national sectoral instruments". Despite this fact, this is the only public mention where the National Platform considers the Sendai Framework; according to our findings, there is a Chilean Sendai Network within the platform, which monitors the Sendai indicators' compliance. This network is confirmed by representatives of the ministers and public services.

In August 2019, **Ecuador** formalized the "National Agreement for Disaster Risk Reduction 2030" [47]. Composed of five thematic axes, the agreement foresees promoting prior approval, the enforcement of the "Law of the Organic Code of State Security". Heading towards adopting national DRR strategies, the thematic axes include:

1. Incorporating disaster risk management into national and local planning.
2. Promoting of the "Law of the Organic Code of State Security" and its chapter "Decentralized national system of risk management".
3. Controlling the accountability of the Ecuadorian Construction Standard (NEC).
4. Building financial mechanisms for disaster risk management.
5. Agreeing to public-private actions for disaster risk management.

In 2019, SNGRE (Servicio Nacional de Gestion de Riesgos y Emergencias—National Service for Risk and Emergency Management) published its updated "Specific Strategic Plan for Disaster Risk Management 2019–2030" (PEEGRD) as a short, medium and long-term planning instrument thought to guide actions at all levels of government through the "National Decentralized Risk Management System" [48].

In addition, in the PEEGRD, other instruments for land management and land-use (in the area of planning), are worth highlighting. Although the Organic Law on Land-Use and Management (LOOTUGS) does not make a direct reference to DRR, it prescribes that local governments must identify natural and anthropogenic hazards within their territories. It is through the land-use and management plans, particularly through the "Territorial Intervention Areas" (PITs) that strategy number 5 of the PEEGRD finds correspondence. However, in the absence of a system to monitor and evaluate the cross-cutting nature of the implementation of these actions, it is not possible to indicate how effective these national initiatives are and/or will be.

In 2019, the Technical Secretariat "Planifica Ecuador" (STPE) published, in a collaborative effort with SNGRE, a guideline for the formulation/update of PDOTs (Guidelines for the inclusion of disaster risk management in the Development and Territorial Planning Plan). While such guidelines came as a series of efforts to land the executive's instruments though sectoral scopes (digitalization, participation, climate change, risks, etc.) to the administrative levels (GAD), SNGRE's guideline addresses the aspect of "Strategies to guarantee the progressive reduction of risk factors or their mitigation, from the central government". However, while such guiding documents are thought to aid PDOT formulation, GADM (the local administrative units) are free to choose whether to use these, to concentrate their views on one or some, as well as to pick discretionally some of their contents.

Indicator E-2. *Percentage of local governments that adopt and implement local disaster risk reduction strategies in line with national strategies*

In **Chile**, ONEMI proposes a specific format for the territorial units (national, regional, communal) to prepare their respective Disaster Risk Reduction Plans [46]. According to the findings of our interview, ONEMI reports a high percentage of municipalities that have DRR plans, but with different levels of development. However, ONEMI does not monitor the progress of the municipalities in the preparation of these plans. The development of these plans is voluntary. Additionally, not all of them are aligned with the Sendai Framework.

Additionally, the "Natural Hazard Analysis Guide for Land-Use Planning (SUBDERE) is also used by local governments to develop their respective plans, but it was prepared prior to the Sendai Framework, so it does not include such indicators. The Chilean Association of Municipalities (AMUCH, Región Metropolitana, Chile) conducted the cadaster of municipal capacities for Disaster and Emergency Risk Management in which a national-

wide sample of 247 municipalities was counted, equivalent to 70% of all local governments. According to this report, 87.2% of the municipalities in the sample declared that they have a unit in the municipal organization dedicated specifically to disaster risk management [49].

However, there are great differences in relation to the capacities that these offices have in each municipality. Using a commune's development typology from SUBDERE (the "Natural Hazard Analysis Guide for Land-Use Planning"), it appears that between large metropolitan communes with high and/or medium development, 28% have a Risk Management Directorate (with their own resources) and 45% have an Office or Department. On the other hand, among semi-urban and rural communes with low development, 48% have an Office or Department, while 36% have only one person in charge of the subject. The AMUCH study indicates that of the sample [49]:

- 41.8% of the municipalities have a Community Plan for Civil Protection and Emergencies in force,
- 31.2% consider aspects related to disaster risk management in their respective Community Regulatory Plans,
- 24.9% declare that they have a specific management plan for disaster and emergency risk reduction,
- 48.3% have an exclusive budget to carry out actions in disaster and emergency risk management.

In **Ecuador**, the GADMs have adopted local DRR strategies based on mainly three instruments:

1. "Cantonal Emergency Plans" (CEP); mainly response plans.
2. "Risk Reduction Agendas" (RRA); focused on transport infrastructure (sea and river ports, bridges, roads, land terminals) and water (water sources).
3. "Risk Management Units" (UGR); mainly preventive, created by municipal decree and if existing, with multiple constitutional and financial allocation variation.

The first two, pushed from the central government are mainly specific and vary from GADM to GADM. Currently, not all GADMs have CEP and/or RRA. In the case of UGR, these are pushed by the GADM and are directly connected to the mayor's office. Currently, not all GADM have UGR.

It can be expected that through the "Guidelines for the inclusion of disaster risk management in the Development and Territorial Planning Plan (PDOT)", GADM will consider DRM as a transversal axis, inherent to planning and development plans. The degree of such inclusion is to be seen; exact numbers are not available. While PDOTs were originally foreseen to be submitted to STPE by March 2020, a new deadline, due to COVID-19, has been set towards the end of 2020. On the other hand, and in the spirit of a bottom-up strategy and monitoring, there is an initiative from the private sector, namely from the "Association of Risk Professionals" (together with SNGRE, the Association of Municipalities of Ecuador and INEC) of developing a "Risk Management Index" that can be adjusted to the GADs' competencies and monitored within the GADM's institutional setup (and budget). While this initiative may unquestionably strengthen the relevance of DRR, it misses the leverage of the UGR's empowerment as an institutional option from within the local and municipal constituencies.

The "Guidelines for including DRM in the PDOT" refer to the Sendai Framework but are not necessarily linked to targets A, B and C. In the case of D, the PEEGRD could be considered as the National Strategy. Several of the strategies from both PEEGRD and the "Guidelines for including DRM into PDOT" have so far been reflected in response preparations (mainly simulacrum and public awareness campaigns).

Indicator G-2. *Do Chile and Ecuador have multi-hazard monitoring and forecasting systems in place?*

Chile does not have multi-hazard monitoring and forecasting systems. However, the Early Warning Center (CAT) gathers information from the reports of different technical

bodies of the National Civil Protection System, to create alerts per hazard. Thus, different hazards are monitored and forecasted by different technical bodies at national level [50].

- The Hydrographic and Oceanographic Service of the Navy (SHOA) monitors the risk of tsunami.
- The National Seismological Center monitors earthquakes.
- The National Service of Geology and Mining (SERNAGEOMIN) monitors geological and volcanic risks.
- National Forestry Corporation (CONAF, Santiago, Chile) monitors the risk of forest fires.
- The Chilean Meteorological Directorate monitors and forecasts all weather events at national level.

In **Ecuador**, the National Information System (SNI), which was introduced in 2008, is responsible for coordinating risk assessment. It provides inputs and basic cartography that allow planning of the territory. To fulfill this task, the SNI works together with different institutions, which conduct research on their respective field of expertise. They estimate and evaluate risk, observe and analyze disasters, and develop hazard maps.

Due to the fact that the development of hazard maps is the responsibility of different institutions, depending on the kind of hazard, there are no defined standards for their elaboration. Most institutions are in charge of single hazards, so the hazard maps are usually single-hazard maps and do not consider multi-hazard effects.

The tsunami and flood monitoring system at national level has advanced substantially, but is not articulated into a unitary system. Monitoring and evaluation is done separately by INAHMI (Instítuto Nacional de Meteorología e Hidrología, Quito, Ecuador), CIIFEN (Centro Internacional para la Investigación del Fenómeno de El Niño, Guayaquil, Ecuador), INOCAR (Instítuto Oceanográfico de la Armada, Guayaquil, Ecuador), IIGE (Instítuto Geofisico) and Ecu911 (emergency call number). Some impulses towards integration have been observed from the Ecu911, even though these exceed its competences, questioning its long-term sustainability. Ecuador has experience in evaluating susceptibility to mass movements with various methodologies and scales, mainly on a specific basis. Efforts at the national level include those between the IIGE and the SNGRE where the susceptibility to mass movements was zoned at the national level on a scale of 1:50,000 and 1:25,000 (2014). Susceptibility maps by IIGE were published for the provinces of Chimborazo and El Oro at a scale of 1:50,000 (2013) and a Susceptibility Map at a scale of 1:1,000,000 (2014). Monitoring is reflected mainly in punctual situations and rendered as diagnostic.

Indicator G-3. *Number of people per 100,000 that are covered by early warning information through local governments or through national dissemination mechanisms*

In **Chile**, the Early Warning Center (CAT) is the unit within the National Emergency Office that makes a constant monitoring in real time of the national territory, and disseminates the alerts to the Civil Protection System. It heads and manages an informational system that receives reports and demands from the National Civil Protection System. Thus, it manages monitoring through the Regional Early Warning Centers and the different technical bodies of the National Civil Protection System. The presence of these Regional Early Warning Centers is fundamental to keep an interlinked system, in coordination with the National Early Warning Center [51].

The alerts that CAT makes can be declared for one or more communes, provinces or even regions across the national territory. The number of resources, services and organizations involved varies according to the coverage of the alert. The CAT makes alerts for surge, tsunamis, earthquakes, volcanic activity, mass movement, geological risk and forest fires. It uses four types of alerts: Green Alert, Early Preventive Alert, Yellow Alert and Red Alert. The early preventive alert is used before the Yellow Alert to strengthen monitoring to possible emergency situations.

Besides this, the Emergency Alerts System (Onemi, Santiago de Chile, Chile), is supposed to send alerts (text, audio and vibration) to all mobile phones in the country

in case of risk to tsunami, high magnitude earthquakes, volcanic eruptions and forest fires. The SAE is implemented by Onemi with the support of the Telecommunications Subsecretary. This massive alert is automatically sent to a georeferenced area according to the alert. In reality, the system has been implemented since 2014, but is only available for approximately 25% of all users of mobile phones [52].

In **Ecuador**, at the national level, there is no information on the dissemination rate of early warning systems. In the case of "tsunami", it is presumed that at least the entire population along the coastal profile enjoys information reported by INOCAR. Its work is relevant for tsunami risks, especially by producing vulnerability studies in coastal areas, flooding maps, and identification of potential risk zones. It aims to establish a National Tsunami Alert System to minimize human and economic losses caused by tsunamis.

Moreover, the Instítuto Geofísico de la Politécnica Nacional (IGEPN, Quito, Ecuador) is responsible for the continuous observation and scientific investigation of seismic and volcanic hazards and the development and application of prevention technologies. It develops hazard maps for volcanic areas.

Finally, the Instítuto Nacional de Meteorología e Hidrología (INAMHI, Quito, Ecuador) generates and distributes hydro-meteorological information relevant for the national development.

Indicator G-4. *Percentage of local governments having a plan to act on early warnings*

In **Chile**, the early warning system operates on a national level. The National Early Warning Center corresponds to a critical unit within ONEMI, which has decentralization at the regional level. This unit is in charge of establishing and disseminating early warnings within the civil protection system at any level. Therefore, at the local level, there are no specific early warning plans.

In 2019, 68% of Chilean municipalities have informed ONEMI [53] that they have a Communal Emergency Plan, which, through standardized formats provided by ONEMI, must indicate how local capacities, endowment of human and technical resources, and materials necessary to face an emergency in its territory are coordinated. It is worth mentioning that between different regions there are differences as to whether or not the communes that compose them have an Emergency Plan. On the other hand, there are communes that have specific emergency policies by threat variable.

The emergency plans include concept definitions on preparedness and response strategies based on early warnings, but no proper strategies suited to every local context.

It is estimated that in **Ecuador**, out of the 221 municipalities (total), only those along the coastal profile (incl. Galapagos) (no. of municipalities: 40, 18%) have a plan to act on the tsunami early warning system [54]. In the case of the volcanic threat (volcanic eruptions), it is estimated that only the exposed regions have a plan to act, namely: Cotopaxi: (no. of municipalities in the influence region: ~8–10, ~3–5%) and Tungurahua: (no.: ~12, ~5%).

For earthquakes, there are seismographs at the provincial level located along the most important faults, such as Quito and Puna–Pallatanga, etc.; they do not necessarily contribute to an early warning system, but rather report on earthquakes that have occurred.

Although a change in the risk paradigm is recognizable, emergency management plans at national and local levels are mainly available for single critical infrastructures (such as airports, electricity and water supply), and hazardous industries (chemical production, waste deposits).

Indicator G-5. *Do Chile and Ecuador have accessible, understandable, usable and relevant disaster risk information and assessment available to the people at the national and local levels?*

In **Chile**, there is systematic information available in relation to risk management strategies and plans at the national, regional and local levels. The national and regional levels of information are available through the ONEMI's website [55]. Although ONEMI works with updated disaster risk information that is aligned to the Sendai Framework, this has not been disseminated yet, as it waits for the approval of the new PNGRD and its consecutive instruments. ONEMI lacks comprehensive actions for all DRRM processes, as

it focuses mainly on emergency response. Additionally, it lacks resources and knowledge to lead the DRM system nationwide [27]. Meanwhile, the local-level information is available through each municipality website. Nevertheless, as the information and plans respond to national standards, it may lack an in-depth analysis of the local situation, which can make it irrelevant in some cases.

Additionally, the "Chile Preparado" viewer aims to become the national-level tool to inform about the volcanic, tsunami and forest fire risks. Thus, the viewer does not add a complete multi-risk perspective. Even though it is a national-level tool, it manages information for the local level. It is accessible to everyone and with available information to be downloaded for private use. Its main objective is to be used by the community for their preparation actions towards these threats. It includes information about roads, topography, location of schools and educational centers, health centers, firefighters, police, and the state of border crossings; as well as evacuation areas, meeting points and evacuation routes in the event of a tsunami threat, and meeting points in the event of a volcanic threat [56].

According to objective 2 of the Institutional Strategic Plan, in **Ecuador**, the SNGRE aims to increase the culture of risk management in the citizenry. Strategies were developed, like the encouraging of training and participation, the generating of spaces for citizen participation or the promotion of knowledge and awareness of risk.

Ecuador has accessible, understandable, usable and relevant information available, mainly in terms of communication material. On the other hand, it is important to underline that most of the data on threats is not necessarily of open access. Upon request, the obtained information is codified by the issuing organization. In addition, available data is of descriptive nature and it is missing an analytical scope (possible reason for which PDOT also limits their scope on risk by limiting to the description of hazards).

The website "Ecuador listo y solidario" provides understandable information about volcanoes, tsunamis, inundations, earthquakes, wildfires and mass movements and gives recommendations about how to act in case of a disaster [57].

There is a national cadastral base at 1:1000. The vast majority of GADM has a record on past events. About 75 GADM (out of the 221) have created their respective UGR and about only 12 have begun to incorporate the "risk" component in their PDOTs and land-use and management plans as a development mechanism (e.g., Cuenca, Portoviejo, Loja, Riobamba, Ibarra, Ambato, Salinas and Machala).

Indicator G-6. *Percentage of population exposed to or at risk from disasters protected through pre-emptive evacuation following early warning*

In **Chile**, information is not available or does not exist in relation to the percentage of the population exposed to risks protected by preventive evacuation. ONEMI has evacuation plans for communes and/or risk areas [58]. In addition, it has general plans for kindergartens and educational establishments, although they lack depth. Evacuation drills are held periodically in different communes, according to the type of risk present (tsunami, earthquake, volcanic eruption) [59]. There are successful cases of evacuation (Coquimbo Earthquake and Tsunami 2015) and cases where evacuation failed disastrously (Maule Earthquake and Tsunami 2010).

In **Ecuador**, no data are available at the national level. SNGRE has certified the identification of evacuation routes, safe zones, etc., but at the GADM level, there is, overall, no linkage and/or coordination with other local, provincial and national authorities in terms of the layout of roads and critical infrastructure.

6. Discussion

Chile and Ecuador share similar hazard profiles, which explains the observed similarities regarding the risk assessment approaches. Both countries have specialized technical institutions for monitoring and forecasting specific risks, and maintain freely accessible information regarding disaster risk at the national level.

From a political-administrative perspective, both countries have centralized governments. Disaster risk management is organized through a top-down approach, which means that the local level does not possess self-governed rights. Both countries have conducted instructions to foster and ensure the inclusion of DRR perspective in local plans, in line with national strategies. Nonetheless, only the existence of guidelines to include DRR perspective could be insufficient, considering the technical and financial limitations that most of the local-level administrations deal with. As Valdivieso and Andersson argued [60], a deeper understanding of disaster risk management performance requires multiple dimensions and factors. Specific local institutional arrangements and relationships between actors such as municipal councils and institutional actors at other governance levels, such as regional governments, ministries, and NGOs, play a decisive role for the quality of risk management schemes. Both countries widely disregard public participation and risk communication which are highly acknowledged as key elements of risk assessment [61] as well as management [62,63]. This is a key root cause for the given vulnerability. Another shared key vulnerability factor is the considerable amount of informal settlements in hazard prone areas and consequently, the attention of both national government's spending to resettlement schemes [64,65].

Although this applies for most of the countries, it is a significant drawback that in countries like Chile and Ecuador that are characterized by multi-risk profiles, this perspective is not yet established and none of the countries has a robust and consolidated strategy in relation to multi-risk monitoring and management [23,35] and cascading effects of disruptions of infrastructure services [66]. However, the recognition of critical infrastructure is becoming relevant, especially after the latest disaster events such as the 2010 earthquake in Chile [67] or the Rio Coca Erosion vis a vis the Central Hidroeléctrica Coca Codo Sinclair + oleoductos in Ecuador [68], but it is still necessary to advance towards a precise definition of what the term refers to, and above all, to a comprehensive analysis of criticality in the face of multi-risk scenarios and cascading effects.

Climate change as a trigger for hydro-meteorological extremes is well acknowledged in both countries [69,70]. Climate change adaptation surely stimulated the political attention to extreme events. Disaster risk management can considerably support adaptation to climate change and vice versa [71], but it has to be noted that the existing fundamental differences between CCA and DRM are widely ignored by the key policy documents in Chile and Ecuador. While disaster risks are normally probabilistically assessed by means of statistics from past events that inform hazard and risk maps, climate change impacts are always scenario-based, and project potential future, deeply uncertain changes of extremes, but also creeping changes of the climate and, subsequently, the environment [72].

Both countries mainstream disaster risk management into land-use planning. Land-use planning is especially important in the phase of prevention, which aims at a reduction of damages to people, property, and resources before a disaster strikes [73]. Further, spatial planning can also play an important role in the phase of reconstruction in the aftermath of a disaster by taking care of a better and more sustainable reconstruction of cities and human settlements (e.g., the principle of "build back better") [1].

A particular strength in **Chile** is the advanced disaster risk preparedness and response, combined with its well elaborated building standards [20]. Moreover, a common procedural framework for the territorial levels for the analysis and management of disaster risk is in place, which means, on the contrary, that risk reduction and management plan formats are, in some cases, not adequately adjusted to the local situation. Chile owns also a high response capacity at the middle and high levels of the administrative structure which makes it possible to fill the existing gaps in the local units. Nonetheless, there are some weaknesses. The national strategies are not yet aligned to the Sendai Framework.

The central level of administration holds most of the trained professionals and capacities to train personnel in DRR [74]. Moreover, in recent years, the study and monitoring systems are improving and strengthening the early warning and monitoring systems at regional level [28]. The largely varying resources between municipalities lead to fundamen-

tal differences regarding the implementation of disaster risk management and reduction strategies. The given lack of community-based strategies in Chile was also emphasized by Sandoval and Voss and identified as a root cause of vulnerability [75]. The importance of financial resources was proved by a statistical analysis which Silva Bustos and Mena Amigo did for Chile [76]. The municipalities that show a moderate to low dependence on the common municipal fund have a low disaster risk, related to greater financial autonomy and own or self-management of resources, and the municipalities with lower percentages of poverty by income are better evaluated. This observation is fully in line with our own findings on the, compared with the rest of the countries, outstanding performance of the capital cities of Santiago de Chile and Quito—mainly due to the given financial resources and institutional capacities (see chapter 4). However, there is currently a new constitution in Chile under development, which may lead to a devolution of power and consequently aims to strengthen the governance of local administrators to reduce the risk disasters' factors and allow to mitigate conditions of existing vulnerability. This should go hand in hand with sufficient economic resources at the level of municipal governments, but also single households to benefit from their new upcoming constitutional rights.

Overall, there is still little participation and empowerment of citizens in the elaboration of communal civil protection plans in Chile [34]. The cadaster prepared by AMUCH (Región Metropolitana, Chile), even though it provides relevant information of municipal progresses, presents methodological inconsistencies: (1) it generates percentages from the sample that participated in the study and not from the total universe of municipalities; and (2) the methodology considers a self-declarative cadaster and not an empirical finding. In particular, there is lack of an adequate incorporation of multi-risks which is relevant as in the massive urbanization in eastern Santiago on the geologically active San Ramón fault [77].

Over the decades in **Ecuador**, the changes in the governance structure and the outcomes in the national and local DRR following the decentralization process, have made visible the reality of disparity between municipalities. In a country, where national equality in living standards, access to public services and the right to the city are among the main objectives of its constitutional mandate [78], the least prepared local governments face the challenge of complying and leading public affairs with limited institutional capacity and budget. Therefore, the success of the performance of local government assuming and managing DRR is increasingly seen as conditional on the specifics of each context. It is essential to acknowledge that two local governments have not the same politico-administrative approach, although being part of the same national territory [79].

Ecuador rewrote its National Constitution, which was approved by public referendum in September 2008. In this new Constitution, risk management is considered a State policy, proposing risk reduction measures through disaster mitigation, recovery and the improvement of social, economic and environmental conditions, to minimize vulnerability. Following this new criterion, the National Decentralized Risk Management System was created, establishing an institutional and regulatory framework to decentralize risk management and incorporate it in planning and development of instruments at all levels of government. Furthermore, Ecuador became the first country to recognize the Rights of Nature and the Right to the City in its basic law—a significant first step for humanity towards a change of paradigm. It includes the chapter: Rights for Nature, whose articles recognize that nature in all its forms of life has the right to exist, persist, maintain and regenerate its life cycles.

Again, after the 2016 earthquake, the institutional risk framework was strengthened. Specifically, the public health sector validated its disaster care protocols, preventing a number of local diseases' spread, but the national government and local government levels respond to different agendas and lack in coordination.

Interestingly, there is a regulatory framework linked to informal settlements, since the "Organic Law on Land-Use and Management" (LOOTUGS) recognizes in its § 74 "de facto settlements" as those characterized by a form of land occupation that has not been

considered by planning, or that is in a risk zone [...] [80]. The LOOTUGS recognizes the role of the municipalities (GADMs) in their exercise of the "Organic Code of Territorial Organization, Autonomy and Decentralization" (COOTAD), in avoiding illegal invasions or settlements (§ n458 COOTAD). While risk management is defined by COOTAD as a competing competence for GADM, it does not have any funding allocation from the central to the local government. Local governments cannot follow up on the multiple top-down resolutions because of a lack of funding, staff and technical expertise.

Although the regulatory framework is well established, there is still an informal market of land. Beyond the evident urban poverty belts, there is strong weakness in controlling and/or steering the land market. Overall, the operability and implementation of the regulatory frameworks is still weak, specifically and mainly in mainstreaming inter-institutional cooperation schemes at different governmental levels and sectors.

Considering the nature of prioritization of development projects along the Guidelines for the inclusion of disaster risk management in the Development and Territorial Planning Plan (PDOT), none of the existing instruments inform a set of criteria which could aid prioritizing works and development projects that could reduce risk exposure.

Regarding the assessment of disaster risk, there are two specific shortcomings apart from the aforementioned lack of attention spent to multi-risk. First, the institutional perspective to "risk" is equal to "threat" and hinders integrated planning. Second, in the identification of risk areas and evacuation routes, there is a lack of active involvement and empowerment.

7. Conclusions

As outlined by the discussion section, both countries show considerable progresses in regard to the implementation of the UN-ISDR strategies, but we doubt that the existing global monitoring approach is appropriately designed for measuring the real situation in disaster risk assessment and management on the ground. The four output indicators target important objectives for disaster risk reduction, but there is, based on this study, no evidence that the chosen input indicators are adequately selected for explaining the observable pathways of the various countries towards the desired more sustainable development. For achieving sustainability, more participatory and inclusive approaches that aim at community-based strategies are required. In addition, multi-risk settings and cascading effects, caused by service disruptions of critical infrastructures need to be understood and addressed more adequately for resilience building.

The global monitoring is primarily designed as enforcement control (input indicators), combined with a control of target achievements (output indicators), but lacks a real control of the effectiveness of the existing disaster risk management, which cannot be done based on purely quantitative variables, but requires local knowledge gathered from document analysis, surveys and interviews. Our comparative study underlined the importance for more qualitative, in-depth studies on the root causes of disaster risk which could complement the global monitoring which is very much focused on quantitative data. This data basis is not sufficient for explaining the country's performance in regard to the global output targets.

Therefore, the set of indicators for the global input targets E and G should be complemented accordingly by key quality criteria of national as well as local disaster risk reduction strategies. These quality criteria should also be addressed by the national reporting requirements. Instead of providing just quantitative information, the countries should specifically address the four key priorities for action of the Sendai Framework. Currently, the common input targets of the Sendai Framework and the SDGs and consequently, the global monitoring, only partly address the key priorities of action of the Sendai Framework, which, for itself, surprisingly well describes the aforementioned weaknesses in Chile and Ecuador:

Priority 1 of the Sendai Framework targets the understanding of disaster risk: "Policies and practices for disaster risk management should be based on an understanding of disaster

risk in all its dimensions of vulnerability, capacity, exposure of persons and assets, hazard characteristics and the environment" [1] (p. 14). Here, the need for a clear evidence basis is outlined which is widely missing in both countries regarding multi-risk settings and cascading effects. Priority 1 also reflects the global input target G on early warning.

Priority 2 aims at strengthening disaster risk governance to manage disaster risk: "Disaster risk governance at the national, regional and global levels. Clear vision, plans, competence, guidance and coordination within and across sectors, as well as participation of relevant stakeholders, are needed" [1] (p. 17). This priority enlightens the key role of land-use planning as a comprehensive, over-sectoral actor on the local level, which lacks sufficient resources in both countries.

Priority 3 tackles investments in disaster risk reduction for resilience: "Public and private investment in disaster risk prevention and reduction through structural and non-structural measures" [1] (p. 18). Thus, economic resources are crucial—which is one of our key findings from both countries. Priority 4 is about enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction phases, which is a critical opportunity for integrating disaster risk reduction into development measures, and thus, making nations and communities resilient to disasters. Again, it is land-use planning which is regarded as an important actor for Priority 4: "[. . .] use opportunities during the recovery phase to develop capacities that reduce disaster risk in the short, medium and long-term, including through the development of measures such as land-use planning (. . .)" [1] (p. 21). The widely unsolved problem of informal settlements in hazard prone areas was identified by this study as a common problem in both countries.

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Abbreviations

AMUCH	Chilean Association of Municipalities
CAT	Early Warning Center
CEP	Cantonal Emergency Plan
CIIFEN	International Center for Research on the El Niño Phenomenon
COOTAD	Organic Code of Territorial Organization, Autonomy and Decentralization
DMQ	Metropolitan District of Quito
DRM	Disaster risk management
DRR	Disaster risk reduction
GAD	Administrative levels of Ecuador
GADM	Local administrative level of Ecuador
IGEPN	Geophysical Institute of the National Polytechnic School
IIGE	Geological and Energy Research Institute
INAMHI	National Institute of Meteorology and Hydrology
INOCAR	Oceanographic Institute of the Navy
LOOTUGS	Organic Law on Land-Use and Management
ONEMI	National Emergency Office
PDOT	Development and Territorial Planning Plan
PEEGRD	Specific Strategic Plan for Disaster Risk Management 2019–2030
PENGRD	National Strategic Plan for Disaster Risk Reduction 2015–2018
RRA	Risk Reduction Agenda
PNGRD	National Policy for Disaster Risk Reduction
SDG	Sustainable Development Goal
SNGRE	National Service for Risk and Emergency Management
SNI	National Information System
STPE	Technical Secretatiat "Planifica Ecuador"
SUBDERE	Natural Hazard Analysis Guide for Land-Use Planning
UGR	Risk Management Unit
UN-ISDR	United Nations International Strategy for Disaster Risk Reduction

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