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List of Abbreviations

DEM	Digital elevation model
DSS	Decision support system
EU	European Union
GIS	Geographic information system
ITC	International Institute for Geo-Information Science and Earth Observation
Mw	Moment magnitude
NDVI	Normalized Difference Vegetation
PGA	Peak Ground Acceleration
WUI	Wildland-urban-interface

Chapter 1 Introduction to the Booklet and to the ENSURE project

The present booklet is aimed at introducing the reader to the logic and the main results of the ENSURE project, a Specific Targeted Research Project funded by the European Union as part of the 7th Framework Programme for Research and Technological Development (for more information about the ENSURE project see Annex 3). In particular, it will show some of the reflections and investigations on vulnerability and resilience that led to the development of an evaluation framework and its consequent application in different case studies. Finally, the main strengths and limitations of the achieved results are discussed, looking ahead at future possible developments.

The ENSURE project set three main objectives. The first objective referred to the operational character of the tool that has been developed. Being able to operationalize the extremely rich and articulated interpretations of vulnerability and resilience was a key motivation for starting the project (Bruneau et al., 2003). A key milestone was the belief that proposed methodologies and scientific advancement in disaster studies should not be considered only per se, but should also serve the fundamental purpose of risk mitigation and losses reduction. At the end, as stated by Winograd (N.d.), the goal of vulnerability assessments should be «turning the data into relevant information and information into action». In other words a fundamental question that was asked throughout the entire project was how a given interpretation, a given tool, can be used for prevention purposes, how it may enhance the capacities of societies to avoid the most dramatic outcomes of natural extremes, and to facilitate recovery. This is also the reason why the project attempted to build on previous knowledge, taking advantage of what has already been accomplished in the field, trying to embed available results of risk and vulnerability assessment experiences as much as possible, in the belief that risk mitigation is inevitably a multidisciplinary, multi-stakeholder endeavour.

The second general objective, responding to the need for operationalization, was to provide an interpretation of the relationship between vulnerability and related concepts (resilience, adaptation, coping capacity, etc.) within a framework strongly targeted towards prevention, following the rationale described in the previous paragraph. The framework had to provide a sort of guideline to assess vulnerability before an event strikes, helping decision makers and even lay citizens take appropriate mitigation and anticipatory measures (similarly, Polsky et al., 2007, Roberts et al., 2009; Longstaff et al., 2010). In other words we were not satisfied with tools that permitted only ex-post analysis, leading to a detailed description of what happened in a given area stricken by an extreme event, but we aimed at being able to identify the weaknesses and fragility that, combined with the severity of an event, may lead to damage and losses in the future.

The third, more specific, goal of ENSURE was to advance in the most "established" field of vulnerability assessment, providing an updated picture of what is already available in literature, in previous studies, and in applications worldwide. We may count already a growing number of proposals concerning indicators, parameters, measures, related to physical, systemic and social aspects of vulnerability. These have been analysed and a selection of the most advanced or appropriate ones were proposed as part of the tool for vulnerability assessment. The result of this more specific goal can be seen in the individual matrices that are part of the integrated framework (see Chapter 4).

In this booklet the discussions on vulnerability and associated terms that were held during the project among partners are not described and readers are referred to the individual project Deliverables (see CD-Rom). In this respect, the project fully acknowledged that vulnerability and resilience were defined and interpreted in different and sometimes divergent ways by decision makers and scientists, even among those who share the same disciplinary background (see Box 1). The variety of perspectives and interpretations were seen by the ENSURE project as a richness rather than as an obstacle, as each definition sheds light on aspects that contribute to explain why a given place, a community, an organization is better or worse equipped and prepared to face and cope with extreme events.

Box 1

History of vulnerability

In the historic development of "disaster" studies, the response to natural extremes has long been attributed to the severity of the stress itself, so that losses and damages were explained with the magnitude of the earthquake, the peak discharge, velocities and height of floods, or the grade on the explosive index for a volcanic eruption. As Weichselgartner and Obersteiner (2002) correctly put it in an article in which they analyse the past and the future of risk research, there is a strong need to move from hazard oriented assessments towards more comprehensive approaches putting at the centre the vulnerability and resilience of exposed systems. Such a need has been increasingly expressed not only by social scientists, traditionally more attentive to the response capacity of societies and individuals, but also by engineers and "natural" scientists, who have become aware of the limitations of structural defences addressing the hazard component alone. When trying to define the meaning of terms such as vulnerability and risk one is faced with the large variety of possible definitions, depending for instance on the "object" focus for assessment. There is no consensus on how to measure and to combine the various intrinsic components of risk, but risk can be considered as a dynamic process with respect to time, and it can be derived basically from the convolution of hazard (probability of occurrence of a particular natural/technical event within a given time-period/geographic space) and vulnerability.

Also for the latter, as for risk, it is impossible to find an agreed definition. Despite the many available interpretations, there are basically three schools of vulnerability conceptualization and assessment (Füssel and Klein, 2006):

1. The first school (Risk-Hazard methodological framework) conceptualizes vulnerability as the dose-response relationship between an exogenous hazard to a system and its adverse effects (UNDHA, 1993; Dilley and Boudreau, 2001; Downing and Patwardhan, 2003). It puts emphasis on exposure either as the principal element of vulnerability or as the pre-condition for vulnerability to manifest itself. In the latter case, exposure and vulnerability are independent from each other and interact with a hazard intervening to generate adverse impacts and losses.
2. The second school (Social Constructivism model) sees vulnerability as the socio-economic origin of differential sensitivity and exposure. It corresponds to the non-biophysical factors of the disaster process (Dow 1992; Blaikie et al. 1994; Adger and Kelly 1999). Here, exposure is viewed as a consequence or an implication of social vulnerability which is the root cause, the origin of both exposure and disaster outcomes (risk).
3. In the third school (most prominent in climate change research), vulnerability includes an external dimension, represented by the "exposure" of a system to climate variations, as well as an internal one, comprising the system's sensitivity and adaptive capacity to external stressors such as climate extremes (cf. The "Hazard of Place" model by Cutter, 1996). Hence, vulnerability is a function and the integrated outcome of exposure, sensitivity and adaptive capacity of a locality or a territorial unit. It refers mostly to geographic contexts, to climate change hazards, to a broad range of impacts and losses. Closely related to this school is a group of approaches, still focused on localities and places, but specifically addressing aspects of vulnerability which are addressable exclusively through land use planning at different scales. They are mostly to be found in some European projects (e.g. ARMONIA Project, 2004-2007).

Chapter 2 A systemic approach to vulnerability and resilience

The conceptualisation of the ENSURE project is that vulnerability is one 'whole' (i.e. a single entity) which has a number of dimensions or facets. Each facet is intrinsically related to every other facet, although the nature of these relations varies, i.e. some are closer or stronger than others. These relations are played out in time and space. The different perspectives proposed by each discipline actually was interpreted as shedding light on what were called "vulnerability facets" that contribute to the overall vulnerability of a given territory and a given society. The vulnerability facets that have been identified are as follows (see Figure 1):

- **Physical vulnerability**, which basically refers to the fragilities that can lead to physical disruption and harm when facing the stress provoked by a given hazard. Physical vulnerability does not need extensive explanation as it has been the most studied by engineers, to explain what are the factors and characteristics that make a given building or infrastructure more or less prone to be damaged under the stress provoked by an earthquake, a volcanic eruption or any other natural extreme;

- A suggested definition for **social vulnerability** could be as the susceptibility to, or potential for, loss of human and social capital and the capacity to recover from these losses. Social capital has no clear, uncontested meaning, and there are almost as many definitions of the term as there are publications about it. However, essentially, social capital is about the value of social networks which affects the productivity and capability of individuals and groups. Close-knit communities are likely to be much less socially vulnerable in disasters than communities where ties have broken down or never existed in the first place. Anything which reduces a community's ability to develop collective, structurally-organised ways of dealing with natural and na-tech events is likely to increase social vulnerability. As for human capital it refers to the level of knowledge and skill which exists in a disaster-prone community, which is in turn related to education and skills levels or investment in these, as well as to experience, which may significantly affect social or economic vulnerability, or both. Clearly, loss of population, particularly if it is skilled and experienced is likely to reduce the amount of human capital available to address hazards and extreme events. Such loss may occur through processes of depopulation or migration, or through loss of, or damage to, life;

- **Economic vulnerability** can be defined as the susceptibility to, or potential for, loss of economic assets and productivity; the loss of the livelihoods these support and the wealth and economic independence they create; financial deprivation and debt dependence; and the capacity for recovering from these losses;

- Vulnerability to losses (see also Polsky et al., 2007) is embedded in the concept of **systemic and functional vulnerabilities**. The main idea in this case is that a system may continue (or not) functioning even though a part of it has been disrupted, or even though systems upon which it depends have stopped functioning. Systems' vulnerability depends in this regard on what Van Der Veen and Logtmeijer (2005) defined as "transferability", "interdependence" and "redundancy" that is relevant not only to economic systems but also to infrastructures, public facilities, community services, etc. Distinguishing between vulnerability to stress and to losses introduces a dynamic component in the analysis that is often lacking in risk assessment, where exposed systems are considered as fixed, while their changeable conditions, particularly after a severe event, are rarely taken into account.

The integral point of the vulnerability facet definitions is that they partially refer to types of vulnerability and partially correspond to the vulnerabilities inherent to given systems. Several systems, for example, may manifest physical vulnerability that is not specific to only material assets. Social agents can be physically vulnerable, given their sensitivity to given threats (leading to injuries after an earthquake, intoxication during a volcanic eruption, etc.). Similarly, organizations display significant physical vulnerability in their own strategic structures necessary to intervene in rescue activities and to manage emergencies.

In the same line of thought, "systemic" vulnerability mainly refers to the weaknesses that derive from interdependency among components of the same system, or among systems and which may lead to functional impairment. In this respect, natural environments, territories, social and economic systems may all suffer from "systemic" vulnerability. The stronger the interdependencies are among systems and system components, the more relevant is the "systemic vulnerability". What is meant here is that there is a certain overlapping of vulnerability facets with systems that manifest vulnerability, so to simplify it can be said that social vulnerability can be intended as the vulnerability inherent to social agents, either individuals, organizations or institutions. Economic vulnerability can similarly refer either to the vulnerability of the entire territory, to its "financial capacity" to pay the costs of the crises and the damage recovery, or to the vulnerability of economic sectors and agents, meaning their capacity (or lack of) to cope and overcome the impact and its longer terms effects.

The various types of vulnerabilities are not separated one from another, they actually influence each other. For example physical vulnerability is often the result of lack of good norms and regulations in the construction sector to build more resistant structures but it may also be the result of poor inspection capabilities, of lack of compliance with existing rules and norms, no matter how well advanced they may be.

The relationships between social and economic vulnerability are particularly close, in fact they are often linked, as demonstrated by the common use of the term 'socio-economic' vulnerability; this closeness means that it is very unusual to find cases in which relationships only operate in one direction. The relationships between different types of social and economic vulnerability to natural and na-tech hazards were illuminated through examining past disaster events; we use as illustration the case study of flooding in Kingston-upon-Hull, England (see Box 2).

A number of common patterns and constant elements were identified in relationships between economic and social vulnerability which suggest elements of predictability that may be built into our developing understanding of vulnerability as a whole. The case studies also demonstrate that one disaster, and the condition in which it leaves an exposed population, may lead to a level of vulnerability which may either reduce or increase the effects of any subsequent disaster; they thus trace the complex cause and effect relationships which exist between the two types of vulnerability. They also highlight how vulnerability is capable of being transferred or 'externalised' (i.e. one agent may off-load vulnerability on to another), and is capable of being transformed over time (e.g. it may be intensified, reduced or be rebalanced). The processes which lead to vulnerability may also operate at different or multi scales, leading to vulnerability at the individual, community, region or state levels.

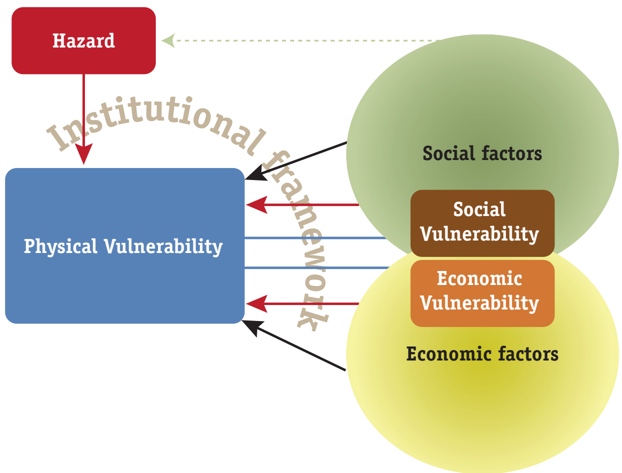


Figure 1: Relationship between vulnerability facets (source: ENSURE consortium)

Thus, social and economic vulnerability exist in a symbiotic relationship (i.e. they reside together) and relations between them need to be considered together rather than as separate one-way relations. Many of the types of social and economic vulnerability which were identified and exemplified illuminate the ways in which economic vulnerability influences social vulnerability and vice versa, but always in the context of physical vulnerability and also usually in the context of institutional vulnerability. Without these contexts it would be very difficult to explain social and economic vulnerabilities and their linkages. Yet despite the closeness of relations between social and economic vulnerability, conceptual understandings of these vulnerability types appear to have emerged largely separately. This means that conceptual integration is under-developed and partial, and therefore still warrants further attention.

Box 2

Case study on interrelations between economic and social vulnerability exemplified by the serious flooding in Hull, England in June 2007

A flood disaster in the city of Kingston upon Hull in the north east of England illuminates linkages between economic and social vulnerability. Hull, with a population of c. 250,000, is located on the Humber estuary which flows into the North Sea. In 2007, the City experienced severe surface water flooding largely owing to the urban drainage system being overwhelmed by rainfall. The flooding affected 20,000 people, over 8,600 houses were damaged, as well as 91 out of 99 schools, and local businesses. A large part of Hull's vulnerability to flooding is explained by (a) the physical characteristics of its location, and (b) social/financial deprivation.

The economic vulnerability of Hull's households and businesses to flooding is intimately related to their social vulnerability, so that sometimes the two types of vulnerability are difficult to clearly separate. For example, the financial deprivation which people faced in Hull was deepened by the flood, and this affected people's stress and anxiety levels and general well-being. Difficulties in keeping up with mortgage payments place household relationships under greater strain, and are linked to ill-health. Those owning and managing flood-affected businesses come under greater strain, not least from the threat of unemployment. People's discretionary spending power declined as a result of the flooding and the higher fixed costs which they had to bare. Through multiplier effects this can have a detrimental impact on the local economy and its ability to recover, although there is usually a counter-balancing effect of increased spending on repairs.

The stress and disruption which families experience when they witnesses their possessions damaged and lost in a flood is significant, and is magnified when they are forced to move out of their homes into temporary accommodation. Disruption of this nature also puts social support networks under greater strain and may erode the effectiveness of social capital. However, in Hull this was countered by opposite tendencies and people were shown to also be resilient in that they exhibited an amazing capacity to cope with and recover from the floods. This resilience took many forms (e.g. the number and strength of informal and formal networks devoted to mutual assistance and community welfare) and reflects an underlying strength of communities and the social cohesion within neighbourhoods. The impacts of the floods appear to have strengthened this social capital, thereby somewhat reducing social vulnerability.

Overall, the effect of economic vulnerability in deepening the social vulnerability of Hull's people and economy to floods appears more influential than the influence which operates in the opposite direction. The floods superimposed a further level of stress and ill-health upon the existing high levels of illness found in Hull, thereby further degrading the ability of the city's population to participate in employment and wealth creation. This had the effect of further weakening economic resilience and also increasing levels of financial dependence. A temporal cycle of vulnerability was observed in which economic vulnerability adversely affects social vulnerability which in turn further affects economic vulnerability in a downward direction.

The various types of relationships shape a more general and integrated vulnerability, where different aspects, social, institutional, economic and physical interact. Such a complex interaction and interplay of vulnerability types can be labelled as "territorial" vulnerability, to make clear that the vulnerability of a region, a metropolitan area or an urban centre is much more than just the sum of the vulnerabilities of individual constructions.

The meaning of territorial vulnerability reflects the propensity to losses and possibilities for recovery of complex geographical entities due to a stressor. These entities incorporate physical, social, economic, cultural, organizational, institutional micro-components and macro-structures. Territorial vulnerability denotes susceptibility to losses of all above components of a territory as well as of their interconnections and linkages. In this sense it is the most complex and inclusive version of systemic vulnerability. Kindred terms are "geographical vulnerability", "urban vulnerability", vulnerability of an area, etc.

The term "relationship" that has been used insofar without any further clarification may sound a little opaque. For this reason we provide some observations and examples in full awareness that several other terms could be found:

- One type of vulnerability may be the root cause or cause of another type: As an example, we may consider an economically disadvantaged region or state (i.e. with a low level of development and limited regional or state resources) incapable to invest in prevention and preparedness measures, consequently suffering from institutional vulnerability. In this specific case economic vulnerability is the direct (although not the root) cause of institutional vulnerability. However, even in this simple and straightforward case, economic vulnerability is not the necessary and sufficient condition for institutional vulnerability to disasters. The cause, i.e. economic vulnerability, does not lead unequivocally to the result, i.e. institutional vulnerability. The respective society may have a strong drive for building emergency mechanisms and planning prevention policies to avoid risks and disasters. Should this specific society decide to spend a large part of its limited budget on risk mitigation it will then avoid the condition of high institutional vulnerability to disasters.
- One type of vulnerability may transform into another type of vulnerability and/or vulnerability of one entity may be transferred to other entities (other components of a system, other sub-systems or other interconnected systems). As an example, entrepreneurs of Small Manufacturing Firms (within informal socio-economic contexts, which are usual in South European countries) after earthquakes and other disaster cases avoid statutory procedures (and the relevant costs) for proper repair of manufacturing buildings and proceed to temporary repairs with the help of low-paid labour from economic immigrants. To secure post-disaster viability of the firm, the manufacturers externalize repair costs and transform/transfer the firm's economic vulnerability to physical vulnerability (of the manufacturing building) and social vulnerability (i.e. exposure of the firm's workers to future earthquakes). These inflicted vulnerabilities may prove fateful in the next seismic event.
- Vulnerability relationships may follow/resemble the types of (structural) relationships existing within or among systems: dependency, interaction, competition, complementarities.

Chapter 3 Vulnerability and resilience: temporal and spatial dimensions

Whilst it may be stated that the relationship among different vulnerability facets as previously described, even though well documented, has not been at the core of most investigations on vulnerability until now, the fact that vulnerability holds relevant temporal and spatial dimensions is well recognised in the literature. According to Turner et al. (2003: 8076) "…vulnerability rests in a multifaceted coupled system with connections operating at different spatiotemporal scales and commonly involving stochastic and non-linear processes".

3.1 Temporal dimension

With respect to time, several aspects have been considered. First, it was recognized that vulnerability should be considered as a dynamic rather than static concept: vulnerabilities are shaped over time, vulnerabilities that we are able to assess today are the result of historic processes, shaping cities, communities, infrastructures in a way that builds their potential relationship with hazards. Considering the different temporal phases of a disastrous event, the need to distinguish between vulnerability and resilience has emerged. Both capacity and weakness aspects, drawn from the scientific literature, have been selected and systematized into a ring-shaped model. The model is articulated in three concentric rings and follows the main phases of the disaster cycle (Figure 2).

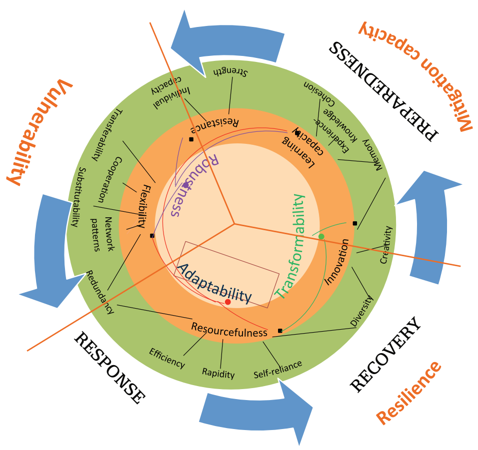


Figure 2: The ring-shaped model of Resilience (source: ENSURE consortium)

The model has allowed us to overcome the interpretations of resilience as the flip side of vulnerability, by highlighting their overlapping and distinct aspects and the relevance of both vulnerability and resilience in the different phases of the disaster cycle.
The analysis of the main capacities making a system resilient in face of adverse events highlights that resilience, including the opportunity for change and transformation after hazardous events, goes far beyond the vulnerability concept. Therefore, elements and systems may be vulnerable to a given event and, in the meanwhile, they can be resilient in that they are able to turn disasters into opportunities. To expand, some capacities, namely the ones revealed in the first phases of the disaster cycle, partially overlap with some aspects of vulnerability. These capacities refer to the potential of a system to withstand the impact of a hazardous event, in terms of preventing or mitigating damage and of reducing losses through an effective management of the emergency phase. These capacities can be adequately investigated in terms of vulnerability.
Other capacities, related to the potential of a system to innovate itself after a disaster and to learn from experience in order to be prepared in face of change, can be better investigated in terms of resilience. It is worth noting that, although some of these capacities come on stage in the recovery or in the preparedness phases, they can influence vulnerability of a community to future hazardous events. Thus, resilience and vulnerability should be separately investigated in the different phases of the disaster cycle, even though - due to their relationships - the influence that some capacities of a resilient system might have on vulnerabilities, need to be taken into account.

3.2 Spatial dimension

The distinction between places that are differently affected during the same event has long been reported in literature (already in Haas et al., 1977): the so called core of the disaster, its “epicentre”, where physical damage is more prominent, and the “periphery” of the event, which is directly and/or indirectly involved in the disaster. In fact, different types of long distance effects can be considered: areas from where help will be provided and to where people will be temporarily evacuated enter into a new type of relationship with the affected areas. New or increased transportation will be required; a flow of goods, services and resources will reinforce and sometime create new linkages. It would be limiting though to consider only the connections arising for emergency and recovery management purposes: remote areas may be affected by the lack of services, by the interruption of major transportation routes or simply because economic relationships exist with the stricken areas, and some firms will be affected by interruption of activities in the impact zone.

3.3 Spatial and temporal scales

In accordance with the already quoted definition of vulnerability provided by Turner et al. (2003), we may take the definition of scale as suggested by Gibson et al. (2000: 219): «We use the term scale to refer to the spatial, temporal, quantitative, or analytical dimensions used by scientists to measure and study objects and processes ... Levels, on the other hand, refer to locations along a scale».
The fact that areas different from those directly affected by an extreme event must be considered, leads to the need to enlarge the overlook from the “local” scale to larger scales, considering how the “local” is placed within larger economic and administrative regions. It is often taken for granted that vulnerability assessment is inevitably local; the ENSURE project challenged such position by showing that a more complex approach is required. It can in fact be held that vulnerability assessments regarding several components of vulnerability are much more tractable at the local scale, and the quality of information that can be gathered is much higher. Nevertheless, the limitations of investigations conducted only at the local level should be pointed out as well.
First, the resources necessary to carry out a thorough survey are limited and therefore many localities will not be covered because of lack of time, money, personnel. In this case, depending on the goal of the assessment, the authority or public administration asking for it, and the type of mitigation measures that can be actually designed, appropriate analytical procedures should be identified. In the case of buildings vulnerability assessment, for instance, a one by one survey can be carried out only in very small municipalities or for a very limited stock. When the appraisal must be extended to entire provinces, counties or regions, sampling techniques or even statistical analysis based on poor data (like census data) have necessarily to be adopted.
Studies at larger scales cannot be considered as less reliable in principle: they obviously serve another purpose, which is the setting of strategies and policies identifying priorities, rather than deciding about individual interventions. This scaling up and down approach can be conducted for what Gibson et al. (2000) call “inclusive hierarchies”, which basically refer to ordering and grouping of phenomena or characteristics that do not significantly change their intrinsic nature and organization at different levels. Actually this type of scaling is needed to make given problems “tractable” as suggested by Wilbanks and Kates (1999).
Second, at the local scale some relevant factors influencing trends and conditions can be missed, as they operate at other scales or levels. The Eyjafjallajökull eruption in Iceland in spring 2010 showed how vulnerable the aviation system is to the consequences of a volcanic explosion provoking ash clouds and

endangering flights. The eruption was a rather "local" event, the consequences of which may nevertheless spread over very large zones; an event that has not provoked significant physical damage, losses or victims, but with a very large impact over transportation systems and through the ripple effects in economic activities on the entire aviation industry, on the tourist sector and generally across the globe.
Third, limiting the analysis to the local scale may be totally misleading in the case of what Gibson et al. (2000) labelled as "nested hierarchies", that are typical of complex systems, and because of which phenomena or systems' characteristics emerge at different temporal or spatial levels in such a way that cannot be suspected looking at lower or higher levels only. A multi-scale, multi-level approach is relevant whenever "emergent" aspects, patterns, relations emerge at higher (or lower) scales and levels and therefore missing them may invalidate the entire assessment: an example is provided by lifelines vulnerability assessment. Because of their intrinsic hierarchical structure and of their mutual interdependence, studies conducted at a local level may completely miss the relevant interconnections that are spatial, temporal, and systemic. Furthermore not just one level is implicated in infrastructure organization: actually it depends on the specific arrangements in a given country. Another example is clearly provided by social vulnerability, as the latter implies the consideration of organizations, associations, and institutions that operate at different spatial and temporal levels with respect to an extreme event. In the case of such emerging aspects a "cyclical scaling" method has to be preferred to rigidly pre-defined "top-down" or "bottom-up" approaches as suggested by Root and Schneider (1995). The framework that has been developed by the ENSURE project, by establishing how given parameters and topics must be addressed at what level and scale, is better fit than case by case analyses to accomplish what Wilbanks and Kates (1999) see as key requirements: to put localized observations into a reference context; and increase the comparability of studies conducted at the same spatial level and across time.

Box 3

Systemic relationships among systems and vulnerability facets across time and space

An example of how connections work over time is provided in the case of forest fires. A sort of "story line" can be drawn from the moment of their occurrence to extinction as shown in Figure 3. The influence of climate contributes to almost all phases of the hazard. Type of vegetation and landscape structure play an important role on fire risk, rate of spread and fire extinction. External causes such as the ones represented in the blue squares directly influence aspects such as fire lighting and vegetation leading to indirect but significant consequences on the hazard chain sequence. Fire fighting is an end line solution to deal with the hazard. On the other hand, we see from the theoretical representation that more should be done in other stages of the hazard in order to minimize the adverse effects. The impact chain identifies the main direct and indirect impacts of a forest fire. The impacts propagate much further into the economic and social system than usually reported. The threat for ecosystems does not only derive from the extent of the burnt area, and it is not confined to the place where the fire occurred. Threats to biodiversity depend on the frequency of forest fires and the impacts propagate in space affecting water courses and population. Population is affected differentially during and after a forest fire. Furthermore, consequences in human health can be traced to locations distant from the occurrence site.

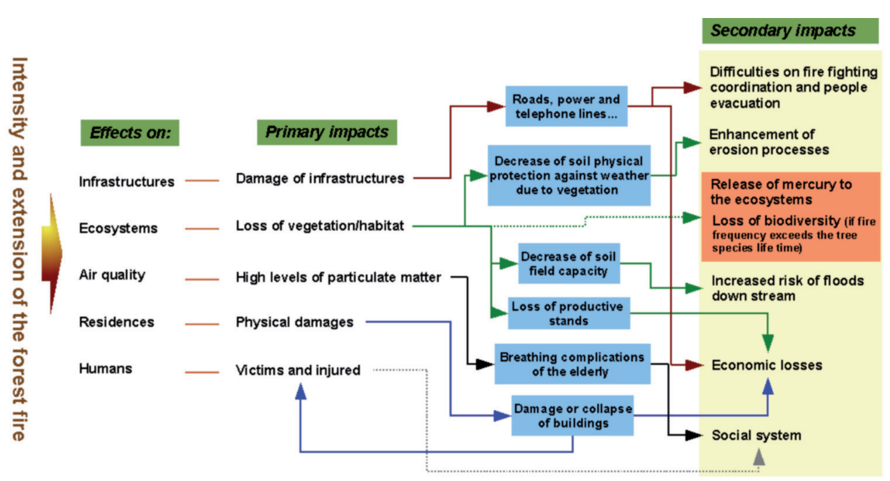


Figure 3: Complex impact chain due to the occurrence of a forest fire (source: ENSURE consortium)

Direct effects of forest fires can be perceived on infrastructures, ecosystems, air quality, buildings and humans. Damage to infrastructure such as roads, communication and power-lines may have an additional impact, making the coordination of fire fighting and possible evacuation actions difficult. The immediate impact of a forest fire on ecosystems is the loss of habitat and vegetation; nevertheless, the secondary impacts after the fire is extinct are substantial and sometimes understated by the media and decision makers tending to focus much more on numbers of forests lost or number of ignitions. Loss of vegetation, and therefore loss of physical support and protection of the soil against weather related phenomena, enhances the erosion process, leading generally to large inputs of sediments into the water courses. Due to lack of vegetation, the field capacity of the soil (the amount of soil moisture or water content held in soil after excess water has drained away) is reduced. If high amounts of precipitation occur after a forest fire, the immediate consequence is a higher risk of flooding on locations downstream since much of the water retention capacity of the soil has been lost. Forests act as mercury traps because mercury in the atmosphere (which comes from both natural and human-generated sources such as coal-fired power plants and municipal waste incinerators) collects on foliage. When the foliage dies, it falls to the forest floor and decomposes, and the mercury enters the soil. When the foliage burns the mercury is released to the atmosphere and then deposited in forests and lakes. The consequences of this release propagate in the ecosystem, for example, fish have a natural tendency to concentrate mercury in their bodies, often in the form of methyl mercury, a highly toxic organic compound. The amount of particulate matter released into the atmosphere (due to the combustion of vegetation) has an impact on fire fighters and populations directly affected by the forest fire. However, due to the aerodynamic properties of these kinds of pollutants (that allow them to propagate in the air) particulate matter can affect other individuals, especially the elderly, in areas that are kilometres away from the forest fire.

3.4 The need for integration

«Improving the understanding of linkages between macro-scale and micro-scale phenomena and processes is one of the great overarching intellectual challenges of our age in a wide range of sciences» (Wilbanks and Kates, 1999: 601). We can suggest that «weaknesses in appreciating the interaction of processes moving at different time scales and extents, in fact, underlie a great deal of the current scientific interest in complexity, non linear dynamics, and the search for order amid seeming chaos». The issue of scale is particularly important when different scientific perspectives must cooperate together in a truly interdisciplinary way. As suggested by Root and Schneider (1995: 334) «the scale at which different research disciplines operate … make multidisciplinary connection difficult and necessitate devising methods for bridging scale gaps». The need for integration derives from the principal scope of the project, which is developing a methodology and relative tools to assess the vulnerability of complex natural and built up environments, including rather than excluding the connection with social and economic vulnerabilities. All the dimensions searched by the various disciplines are essential to this main aim, as each provides a piece of the very complex puzzle needed to describe why and how an urban or a regional context responded to an extreme stress, like an earthquake, a flood or a volcanic eruption.

Having said that, it is clear that what could be realistically achieved within the ENSURE project was first an explicit recognition of the importance to consider the scale issue as a central one, and second a proposal of how it can be operationalized within the proposed methodology.

«The borderline between natural and human sciences has long been a difficult area and is likely to remain so» (Ginzburg, 1980: 5). In his article Ginzburg indicates the role played by the individual as the major difference between the two "sciences": neglected in the Galilean science approach, thanks to statistical methods and to the repeatability of observations in laboratories, whilst inevitably present in social sciences. This very theoretical point will be briefly discussed as it is relevant to understand the type of integration that was aimed at by the ENSURE project among different vulnerability facets analysed according the "right" spatial and temporal dimension.

An initial assumption of the project was that a bridge between the "social" and the "hard" scientists should be constructed to improve the usability of tools provided to decision makers. In the case of vulnerability and resilience studies, we may even go further and state that the point is not just making the two fields communicate, but actually developing good science at the border of the two approaches (and the many more disciplines within each approach) to address issues that cover both i.e. material, physical and human, social.

An essential question that has to be raised is whether or not, and to what extent, risk assessments can be fully labelled as "scientific", in particular when the latter are conceived as the estimation/forecast of damages due to the interaction between natural phenomena and the socially constructed built environment. It may be said that whenever the response component is considered, this inevitably decreases the scientific rigour of risk assessments, as by introducing the human factor, the unpredictable and many times incommensurable is introduced into the otherwise scientific evaluation. Assessing vulnerability resembles the diagnosis process in medicine, a science which somehow lies at the border between the "social" and the "hard" sciences according to Ginzburg. Classification of illnesses and associated symptoms clearly brings medicine closer to "hard sciences", on the other hand, to be effective, diagnosis and prognosis need to tailor both analysis and remedies to the specific characteristics of the individual. Rather similarly, to assess

vulnerability and resilience, on the one hand one must classify, find constant and common patterns in a variety of cases, building a framework that formalises such acquired knowledge with the help of statistical and quantitative methods at least for some indicators; on the other one must be ready to adapt and tailor assessments to specific situations, should useful diagnosis and mitigation measures be proposed.
Neither hazard analysis, though, fully satisfies Galilean method requirements. In fact, when the probability of occurrence of improbable or very low probability events must be appraised, it becomes impossible to eliminate the individual and the exceptional in favour of the constant and the repeatable. This is true for phenomena like severe earthquakes or large volcanic eruptions which by their nature are exceptional – at least as far as historic series permit to record. In the case of other hazards, like for example landslides, the capability to forecast is restricted by the multiplicity and complexity of the physical conditions triggering extreme events. In all those cases, only «retrospective predictions» can be actually made; «when causes cannot be repeated, there is no alternative but to infer them from their effects» (Ginzburg, 1980: 23).
Resilience and vulnerability assessment in its turn, resembles a "medicine" type of effort, where classifications of diseases (in our case classes/categories of vulnerability) and the symptoms to be considered (the indicators) and how to judge their relevance and severity (criteria for assessment) are at stake. Within the framework, some indicators respond more to a Galilean type of science, when statistical methods and sufficient data can be used for their assessment (typically most of physical vulnerability parameters and some systemic in the sense adopted by the project). Many others (typically all those referring to the social and economic systems) will remain at a "classificatory level". The point is therefore whether or not the two types of assessments can or even should coexist in the same framework. We think that even though in a rather imperfect way, the framework provides an acceptable level of integrated vision of the different aspects that must be taken into account in vulnerability and resilience assessments, and without sacrificing relevant fields where knowledge on response of social, built and natural environments to extreme has been produced.

Chapter 4 The ENSURE integrated multi-scale vulnerability framework

In Figure 4 the framework developed within the ENSURE project is shown. As can be clearly seen it is deployed over a plane where both the spatial and the temporal dimensions are evidenced. The scales at which hazards and vulnerabilities are assessed do not necessarily correspond: as for the spatial one, some hazards may be rather localized, as landslides or volcanic eruptions, but the vulnerabilities to them may manifest at much larger scales. As for the temporal scale, the phases of "impact-emergency-recovery" that are shown on the x axe may be troubled by aftershocks or new occurrences of the extreme phenomena. Repeated occurrences may bring back systems to a stage of disruption from a situation of partial return to normalcy achieved thanks to initial successful response.

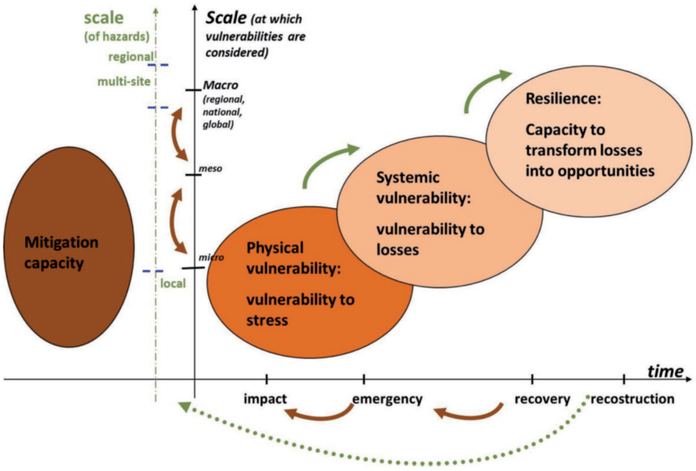


Figure 4: General integrated multi-scale vulnerability framework developed by the ENSURE project (source: ENSURE consortium)

Limiting the attention to the analysis of resilience and vulnerability, it is evident in Figure 4 that an interpretation has been chosen while drawing the ellipsoids in the virtual plane of disaster response. According to such interpretation, vulnerability and resilience are two separated concepts (see Paton 2008). Before the impact, resilience is considered as comprising the set of resources and capacities to prevent the disaster from happening. At the impact, the physical vulnerabilities play the major role: the direct physical damage that can be accounted for are strongly correlated on the one hand to the severity of the hazard, on the other to the level of physical fragility of artefacts and constructions.

As the time from the impact passes, other forms of vulnerability gain relevance, in particular during the emergency phase, precisely systemic vulnerabilities. Those express the response capacity (or lack of) not to the direct extreme event impact but rather to the consequences of the latter, to the impairment in crucial systems and their components provoked by the physical damage. Systemic vulnerability depends much more on the interconnectedness and interdependencies among systems and components rather than on their individual specific features.
Finally, considering the time of reconstruction and recovery, resilience gains prominence: as in the case of systemic vulnerability, the response is not to the stress, but to the longer term induced, indirect, secondary effects it has triggered. What is measured here is not merely a response capacity, but rather whether or not systems are able to recover by reducing pre-event vulnerabilities, to learn from the weaknesses that the event has revealed and to transform reconstruction into an opportunity to build and develop a better, safer and healthier place to live (see Handmer and Dovers 1996; Norris et al. 2008).
As for the spatial scales, it is more difficult to decide in general, abstracting from specific contexts and potential end users, at what scale vulnerability and resilience assessments must be carried out. This is particularly true for mitigation and recovery capacities: the latter in fact entail local deployment of human and material resources, but also national laws, administrative capacity of implementation and control by authorities and agents at different governmental levels, as well as the contribution of economic stakeholders that may reside in areas far from the affected one. Therefore, the choice of the most suitable spatial level must take into account how agents and institutions are organized with respect to a given threat, at what governmental level (national, regional, federal, or as in the case of the EU, over-national Community) laws are passed and compliance is checked.
In this case, a "mapping" approach following the one proposed by Briguglio et al. (2008), see Figure 5, can be followed. In other words, one has to first identify in the case at stake what are the agents and the economic stakeholders that are most relevant for understanding a given pattern of preparedness (or lack of) and of capacity (or lack of) to influence physical and systemic vulnerability and then direct the efforts into the assessment of the elements at different spatial levels that are relevant for the case at hand.

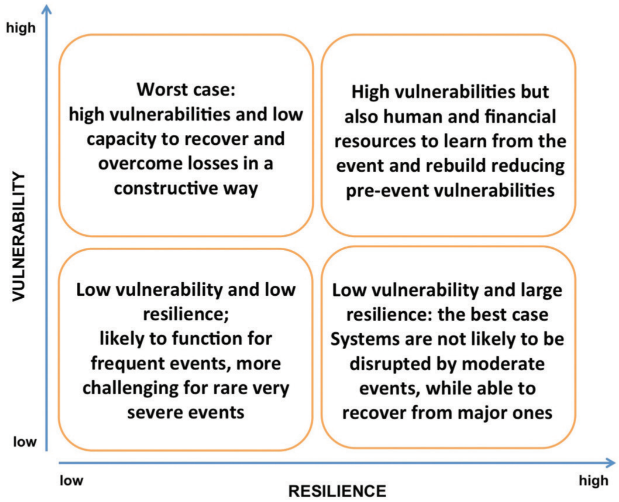


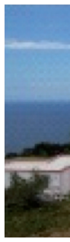
Figure 5: Scheme to sketch the cross temporal scale relationship in a given area and context (source: ENSURE consortium)

As far as physical vulnerability is concerned, scaling up and down and adopting sampling and statistical techniques depends on the final user of evaluations: at a local level, buildings and structures can be easily analyzed individually or grouped by typologies; when the regional or the national built stock must be appraised, clearly a one by one structure evaluation is not feasible and even useless for decision makers and statistical methods must be preferred. Finally, for systemic vulnerability, a scaling approach may be adopted that goes up to the largest spatial scale necessary to identify functionality at lower (local) levels of concern, and conversely widespread consequences of otherwise very localized failures.
The step that has been undertaken by the ENSURE project in order to turn the framework into an applicable tool, consists of translating the ellipsoids in Figure 4 into a set of matrices.
The matrices (see Table 1) are structured by systems to be assessed (represented in the rows grouped by colours) and by parameters related to aspects describing components of the different systems. Parameters are identified by their main target (to be found in the column labelled "aspect parameter") and by the key criteria to be adopted for assessment (the column "criteria for assessment"). The matrices structure shown here represents the final layout comprising the suggestions made by the different working teams in applying the framework to the case studies that will be illustrated in Chapter 5.

System	Component	Aspect	Aspect parameter	Criteria for assessment	Comments/ Case study
Natural environment	Natural hazards	Existence and quality of mapping and monitoring	Specific parameters to permit assessment of the aspects that have been identified as relevant	Criteria may range from binary (yes/no) to degree (corresponding to judgements) or to more physical measures (for example related to time needed for ecosystems to recover).	Specific parameters to permit assessment of the aspects that have been identified as relevant.
	Enchained events	Assessment of hazards triggered by other hazards			
	Ecosystems	Fragility to hazards and to mitigation measures			
Built environment	Residential buildings	Existence and compliance with codes and land use planning regulations	Specific parameters translating into measurable factors of the aspect to be assessed	Criteria for multiple measurement modality are provided; they also depend on the scale at which the assessment is carried out.	Building codes exist for some hazards (particularly seismic) and not for others; nevertheless research in the field of resistance assessment to various types of stress has evolved in the last decades.
	Public facilities	Existence of vulnerability assessment and their consideration on mitigation strategies or in emergency plans			
Infrastructure and production site	Critical facilities	Existence of strategies addressing the interdependency and the functioning of critical facilities under extreme conditions	Parameters to specify conditions at which crucial lifelines and utilities can keep functioning are provided, as well as to address the potential for na-tech	Criteria for assessment are provided; proposed criteria reflect the need to address the interaction across spatial scales of such facilities.	Critical facilities and production sites are clearly part of the built environment. Nevertheless a specific group of rows have been dedicated to them because of their relevance.
	Production facilities	Existence of plans and procedures to maintain production in safe conditions given the possibility of an extreme event			
Social system (agents)	People/ individuals	Weaknesses versus preparedness of individuals	Most of those are qualitative parameters to assess the general level of preparedness and recovery capacity (or lack of) to traumas and discomfort provoked by potential disasters	Criteria for evaluating the parameters are provided, taking into consideration the different spatial scales at which individuals, institutions and economic agents act.	Whilst the previous groups of systems relate more to the "physical environment", clearly this one embeds the results of decades of social sciences research in the field of risk and disasters studies.
	Community and institutions	Weaknesses versus preparedness of organisations and institutions			
	Economic stakeholders	Preparedness and recovery capacity (or lack of) of economic stakeholders			

Table 1: General structure of matrices of ENSURE integrated multi-scale vulnerability framework

The recourse to indicators and parameters seemed the most obvious step: as for illnesses and symptoms classifications, indicators work as clues of weaknesses and opportunities for coping with the consequences of natural extremes. A rather extensive effort has been put into the identification and description of parameters. Meta criteria for quality, cost, effectiveness, usefulness have been carefully examined, while selecting from literature and past experiences the most appropriate parameters. Such thorough work on the one hand scanned and systematized indicators that have already been proposed to assess the vulnerability of places and communities to a variety of threats, which on the other hand either suggested new parameters to fill existing gaps or identified sectors where further investigation is required.
Partially to pursue the systematizing effort and partially to tailor as much as possible the parameters to specific aspects and contexts, it was decided to develop different sets of matrices for different hazards. In fact, not only physical vulnerability is so to say “hazard related”; a community may be well prepared and equipped to face a given stress while completely unprepared for others, which are felt as less severe or probable. The choice to develop “hazard related” sets of matrices does not impede a multi-risk perspective: on the one hand in each set of matrices the possibility of enchained events (hazards triggering other natural or technological threats) is fully appraised, on the other hand sets of matrices can be used in combination in areas exposed to multiple risks, shown in the case studies that follow.
The ENSURE integrated multi-scale vulnerability approach has been applied to a set of in-depth case studies, representing various hazards and considering different scales:



Case study area	Hazard	Scale
Vulcano Island, Italy	Volcanic (tephra, lahar and ashes), earthquake, landslides, na-tech hazards	Local
Ilia Prefecture, Greece	Forest fires, earthquake, floods	Provincial and Regional
Negev, Israel	Droughts	Regional

Table 2: The ENSURE test case study areas

Three further applications were conducted applying the approach to the Municipality of Corvara, Italy, for landslides, the region of Tigray, Ethiopia, for droughts and the city of Istanbul, Turkey, for earthquakes and na-tech hazards, and will be presented in Annex 1.
Results of the tests were integrated into the final version of the multi-scale vulnerability approach and motivated the further development of the framework to fit it within a more dynamic approach.

Chapter 5 The ENSURE test areas

5.1 Vulcano Island, Italy

General introduction and setting

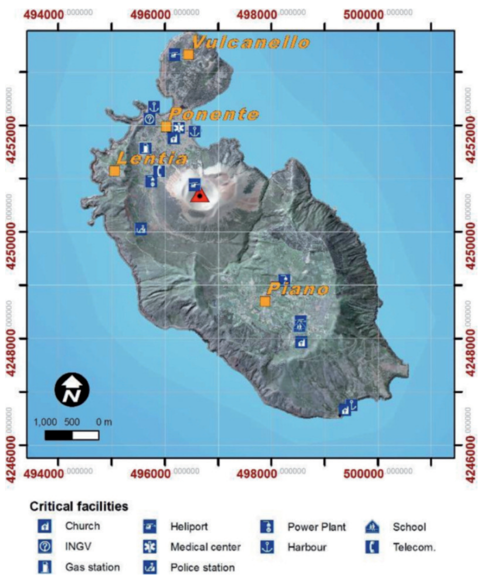


Figure 6: Main features and critical facilities of Vulcano island, Italy (source: ENSURE consortium)

Vulcano is one of the seven islands of the Aeolian archipelago in the Mediterranean Sea (southern Italy) (see Figure 6 and 7) with a surface of about 20 km². In 2006, the official population reached 1,080 people, even though actual residents may number around 600, especially in wintertime, when touristic activities cease. During the peak tourist season, from May to October, between 5,000 to 10,000 tourists visit the Island.
The island is a multi-hazard prone area, in which more dispersed phenomena (such as volcanic ash, seismic events) and localized hazards (lahars, landslides) may occur. In detail, the most current active system on Vulcano is represented by the La Fossa cone, which, during the last 1,000 years, has been characterized by a wide spectrum of eruptive styles, from effusive to medium-intensity explosive activity.

Figure 7: View of Porto town from Lentia and the Aeolian archipelago in the background (source: ENSURE consortium)

The potential for short warning times and proximity of people, buildings and activities on the island to hazards associated with an eruption exacerbate the risk to people and property. Explosive volcanic eruptions typically produce a range of primary (e.g. tephra fallout, pyroclastic density currents) and secondary (e.g. tsunamis, landslides and lahars) hazards, which require independent studies. Vulcano island is highly exposed to all these hazards in combination to the hazard related to tectonic earthquakes.
Vulcano is a small island, which is part of the Lipari Municipality; thus, it represents the only test site at local scale of the ENSURE framework.
For applying and testing the matrices for vulnerability assessment presented in the previous chapter, first of all the areas potentially affected by the different hazardous phenomena and, consequently, the potential exposed targets have been identified. To this aim, specific hazard analyses have been carried out, focusing on volcanic phenomena (and namely on tephra and lahars) and on seismic events.

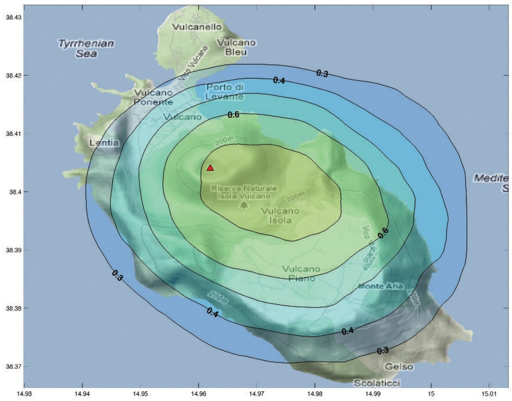


Figure 8: Tephra hazard map showing the probability of reaching an accumulation of 300kg/m2 (source: ENSURE consortium)

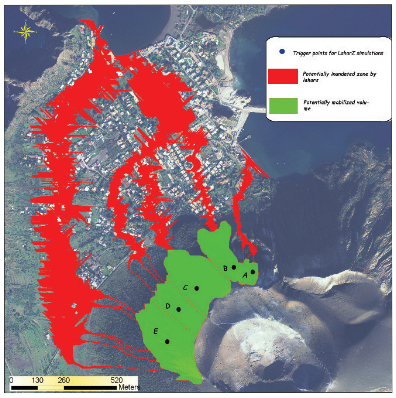


Figure 9: Overall sketch of LAHARZ simulations, including source areas, trigger points and inundated zones (source: ENSURE consortium)

In detail, hazard assessment has been developed for tephra (including ballistic ejecta) and lahar phenomena related to a possible eruption with Volcanic Explosivity Index 3, considered as the most likely scenario based on past activity (see Figure 8). Starting from an accumulation map of tephra deposition and on a digital elevation model (DEM), a simulation addressed to define the areas potentially inundated by lahars has been carried out through the lahar-devoted software LAHARZ (see Figure 9).
Available seismic data confirm a relatively moderate seismic activity on Vulcano. To assess seismic hazard on Vulcano, two scenarios were retained: one similar to the 1981 local earthquake (Mw = 4.7) and one corresponding to the hazard level defined in the Italian building code, which indicated a Peak Ground Acceleration (PGA) of 1.8 m/s2 for the island.

Application of ENSURE methodology

Vulnerability of different areas and targets affected by tephra fallout, lahars and earthquakes has been analyzed with respect to the capacity to prevent and/or mitigate risks, to physical and systemic aspects and to recover from impacts after a calamitous event. Vulnerability analyses have been developed grounding on data and information collected through direct and indirect surveys and organized within a GIS environment, structured according to different types of spatial elements and units: the whole island, the urban fabrics – which represent homogeneous partition of the built areas- the census units, individual buildings and public facilities. Moreover, it is worth emphasizing that, a scoring procedure has been adopted; in detail, starting from the qualitative or quantitative values obtained for each parameter, aggregate values have been calcu-

lated through simple or weighted means among the different parameters. Hence, disaggregate values, related to individual parameters, may allow us to define adequate prevention and/or mitigation measures, whereas aggregate values allow us to compare and prioritize different systems or areas. Furthermore, since in many cases vulnerability of a given aspect or system depends on numerous parameters - which can play different roles and these roles may also change in respect to different territorial contexts - a weighting system has been also introduced. The assessment of the mitigation capacities in the face of the considered hazard factors affecting Vulcano island clearly highlights how knowledge and consequently mitigation policies are still mainly focused on hazard: according to the matrices, the scores obtained with respect to the natural system are generally higher than the ones obtained with respect to the built environment, since exposure and vulnerability analyses are still largely neglected and, consequently, structural defence measures are generally favoured with respect to those aimed at reducing exposure and vulnerability.
The Master Plan of Vulcano mirrors the widespread difficulty to embed risk prevention/mitigation that can be

System	Aspect	Aspect weight	Key-topic	Key-topic weight	Key-topic weight	Key-element	Parameters	Criteria for assessment	Data Quality	
Built environment	Exposure and vulnerability of Urban Fabric n. 1	1	What are the factors that make the urban fabric vulnerable to the stress?	1	Factors related to the features of buildings and public facilities of urban fabric	1	Roof	Connection to structure		
								Weight		
								Shape		
							Structure	Material	Low	Four c
								Homogeneity		
								Type of connection among parts	Not available	
								Floors rigidity		
							Foundation	Depth and type	Not available	
							Spans between resistant elements	Distance in m.		
							Shape	Openings	Not available	
								Quality of openings		
								Basement	Not available	
								Inflammable objects	Not available	
								Sources of radiation or toxic chemicals		
							Maintenance	Building conditions	Low	Fo
							Position	Soil on which the building is built (crest, alluvial deposits, etc.)		
								With respect to dangerous channels	High	Four cla (c
								Distance from dangerous areas (crest, alluvial deposits, etc.)	High	F
							Protection	protection provided by enclosures (type and position)	High	F
							Vulnerability assessment of public facilities	Internal machinery sensitive to the volcanic hazards	Not available	
					Factors related to the urban fabrics morphology	1	Rainproof level of the settlement	Covered surface/surface of urban fabric	High	Fo
								Rainproof surface/surface of open spaces	Medium	Fo
							Activities at ground floor	surface of residential building placed at road level/covered surface of the urban fabric	Medium	Fo
								Surface of basement/covered surface of the urban fabric	Not available	

Table 3: Physical vulnerability to lahar of one of the nine urban fabrics: an example of the ENSURE matrix (source: ENSURE consortium)

seen almost wherever in Italy: although land use plans take formally into account hazard and risk analyses, they do not generally provide measures for reducing exposure and vulnerability of existing settlements and, in some cases, foreseen developments lead to increase current risk features. With respect to seismic risk, it is worth noting that in 2010, based on a national law for re-launching the building sector, Sicily issued a regional Law which allows an increase of 20% in volume for detached or semi-detached houses (very common in Vulcano Island), reserving such an opportunity to buildings which have been legally built up to December 2009 and introducing two further conditions: the control of static condition and the seismic retrofitting of buildings.
Hence, such a law could have negative effects, since it might induce an increase of building density in the areas affected not only by seismic but also by volcanic hazard or by landslides but, in the meanwhile, it represents an opportunity for private interventions addressed to improve physical vulnerability to earthquakes.
In terms of mitigation, aspects related to the level of preparedness of individuals and to the capacity of institutions to improve risk awareness are generally low; some attempts to achieve better coordination among the different institutions in charge of risk management can be recognized, although they are limited to emergency management and are clearly driven by specific contingencies, like the occurrence of a given hazardous event.
Regarding physical vulnerability, a rather extensive and detailed assessment of the physical vulnerability to the main hazards menacing the island (tephra fall out, lahars and earthquakes) has been carried out. An example of the assessment of physical vulnerability to lahars carried out for one of the nine urban

fabrics is shown in Table 3. As for seismic vulnerability, this can be ranked as medium to low: the traditional Eolian architecture is characterized by detached houses with one or two floors and most of them are in a good state of maintenance, providing a good response in face of seismic events.
With respect to tephra fall, buildings have been classified in relation to the features of roofs, distinguishing roofs (plane or pitched) from patios, lean-to roof (tettoie) and pergolas. They have then been classified with reference to the quality of the maintenance level (from very high to low). In addition, a specific study on Vulcano's roofs carried out with the contribution of the University of Lausanne pointed out that with a probability of accumulation of 300kg/m2 of tephra the lower degree of vulnerability regarding a roof is with a pitch of 30°. Thus considering the main typology present on the island, physical vulnerability of roofs to tephra is rather high. In the case of lahars, a rather interesting attempt has been conducted to address the physical vulnerability of urban fabrics in the northern area of the island, which is more susceptible to this hazard, considering both the pattern and the resistance of buildings pertaining to each fabric.

ity	Descriptors	Assessment	Notes on the Vulcano case-study	Scoring parameter	Scoring key-element	Scoring key-topic	Scoring aspect	Scoring System
	good/poor				0,8 = VERY HIGH	0,77 = VERY HIGH	0,77 = VERY HIGH	0,77 = VERY HIGH
	heavy/light							
	large inclination/plane							
	Four classes obtained through the ranking of the index with natural breaks (iron-wood and mixed, masonry, reinforced concrete)	High	The assessment has been developed grounding on in-situ surveys and photos	0,75				
	large/largely dishomogenous							
ble	good/poor							
	rigid/non rigid							
ble	non-existent, deep, superficial							
	> 3 mt; < 3 mt (for masonry mainly)							
ble	number and dimension of windows/doors							
	may be easily sealed/not							
ble	existing/non existing							
ble	existing/non existing							
	existing/non existing							
	Four classes obtained through the ranking of the index with natural breaks (poor/medium/ good/very good)	High	The assessment has been developed grounding on in-situ surveys and photos	0,5				
	amplification soils yes/no							
	Four classes obtained through the ranking of the index with natural breaks (out of the channel/lateral zone/middle zone/central zone)	Very high	The assessment has been developed grounding on cartography and lahars run out analysis	1				
	Four classes obtained through the ranking of the index with natural breaks (low, medium, high, very high)	Very high	The assessment has been developed grounding on cartography and lahars run out analysis	1				
	Four classes obtained through the ranking of the index with natural breaks (low, medium, high, very high)	Medium	The assessment has been developed grounding on cartography	0,75				
ble	yes/no; type of machinery							
	Four classes obtained through the ranking of the index with natural breaks (low, medium, high, very high)	Very high	The assessment has been developed grounding on cartography	1	0,75 = HIGH			
	Four classes obtained through the ranking of the index with natural breaks (low, medium, high, very high)	Medium	The assessment has been developed grounding on cartography and ortophoto	0,5				
	Four classes obtained through the ranking of the index with natural breaks (low, medium, high, very high)	High	The assessment has been developed grounding on in-situ surveys and cartography	0,75				
ble								

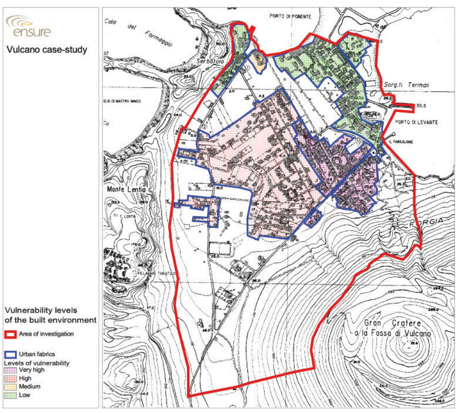


Figure 10: Physical vulnerability assessment of the built environment: final ranking of urban fabrics (source: ENSURE consortium)

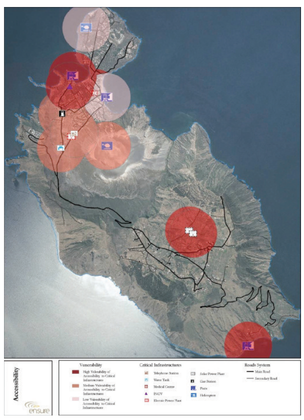


Figure 11: Level of vulnerability of internal accessibility (source: ENSURE consortium)

The assessment revealed remarkable differences among the nine urban fabrics singled out in the area of concern (see Figure 10), allowing the identification of the priority zones on which to intervene for reducing vulnerability and guiding towards the most appropriate mitigation measures.
The assessment of systemic vulnerability has been mainly focused on critical infrastructures and mainly addressed to evaluate potential loss of accessibility; degree of interdependency of some critical infrastructure on the infrastructure network; transferability and redundancy of some strategic equipment (see Figure 11). Based on the assessment developed with respect to seismic events, lahars and tephra fall-out, it is worth noticing that the heliport on the volcano cannot be used as an escape way during an emergency phase due to its high vulnerability. However, the most vulnerable areas in terms of external accessibility identified by this study are Piano and Porto Gelso for different reasons, respectively position and accessibility from inhabited areas. Redundancy and interdependency have been considered as key criteria to analyze the systemic vulnerability of each system (water, communication, electricity, monitoring, health, police force). In case of an emergency, the island of Vulcano would need relevant external support, particularly for water and fuel. In addition, each system is extremely dependant on the others and a low level of redundancy has been reported. As far as preparedness activities are concerned, it has to be underlined that no emergency plan is currently available and the only evacuation drill dates back to November 1991. Considering resilience, the recovery capacity of the island depends very much on the scenario of destruction that is considered. With its high dependence on tourism as the main if not the only economic activity, any loss to the features of the landscape, vital assets like hotels and facilities, may mean a number of seasons without any income, not only for the residents but also for the many who come to Vulcano seasonally to earn their living.

5.2 Negev desert, Israel

General introduction and setting

Being a global phenomenon, droughts impose extra risk on ecosystems and the lives of humans. This is all the more so in drylands where the droughts cause much greater damage. The Negev desert in Israel, an area located between isohyets 100 to 450 mm, is no exception. The vulnerability of the Negev to droughts, as an exemplar for a territorial system in the semi-arid zone, is the subject of the current research.
Known as a "bread basket" of Israel, the major forms of agriculture in the Negev (Figure 12) are large-scale cultivation (between isohyets 200 to 450 mm) principally by Jewish farmers and livestock grazing (between the isohyets 100 to 200 mm) by Arab Bedouin sheep owners. Both populations may be severely impacted by droughts, characteristic of 15 of the last 20 years.
Drought may directly affect the crop yield and thus the economic situation of the Jewish farmer and that of the Bedouin sheep owner. The situation is more complex as both populations are engaged in reciprocal relations, e.g. Bedouin sheep owners buy some of the straw and grains that were harvested from the fields. They also buy the right to graze on the remaining straw left in the field after harvest. Frequent droughts may lead to large-scale bankruptcy and abandonment of fields and settlements. However, adequate protective measures can make the system robust to droughts.

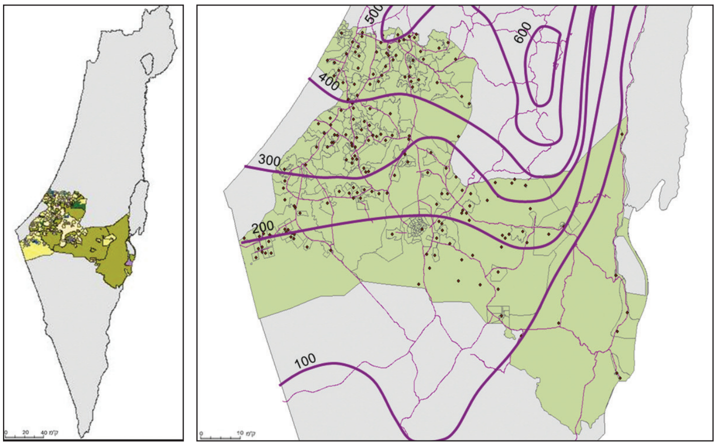


Figure 12: Location of the Negev and the average level of precipitation (source: ENSURE consortium)

Application of ENSURE methodology

Four vulnerability matrices have been constructed to assess the levels of vulnerability/resilience of the agricultural, built, production and social systems in the Negev. Based on the factors presented in the matrices, a series of models have been developed aimed at exploring the vulnerability of both sectors i.e., the Jewish and the Bedouin farmers, to droughts. The models enable estimation of the yield and supply of the food for the sheep for different scenarios of drought development and the development of the irrigation system in every Jewish and Bedouin settlement in the Negev (Figure 13). Our results showed high resilience of both sectors to droughts with the Jewish sector being the driving force. By direct involvement of the government, various institutions, and of the local citizen associations, the (a) water availability was substantially increased, (b) mechanisms were developed to compensate for the loss of revenue, (c) new agricultural techniques and (d) new varieties (of wheat and sheep) were introduced. All these increase coping capacity of the crops and husbandry to droughts. Our model shows high vulnerability of the western, densely populated, part of the Negev with its developed Jewish and Bedouin agriculture (Figure 14).

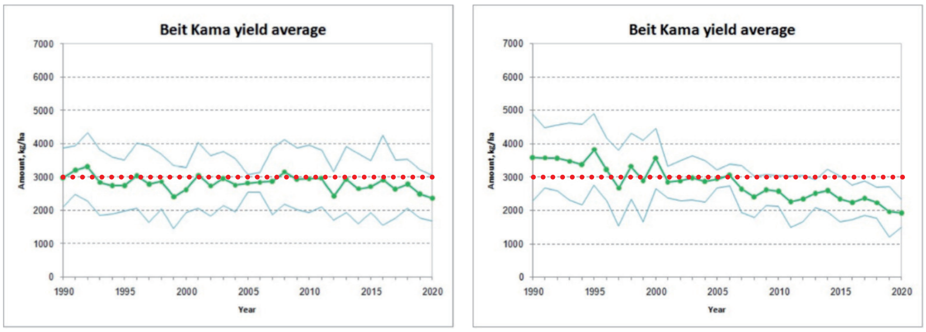


Figure 13: The wheat yield obtained in the model for the Beit Kama kibbutz for the period 1990 – 2020 for the case of (a) precipitation level characteristic of the period 1970-1990 and (b) weather conditions and irrigation system as observed during 1990-2010 and extrapolated until 2020 (source: ENSURE consortium)

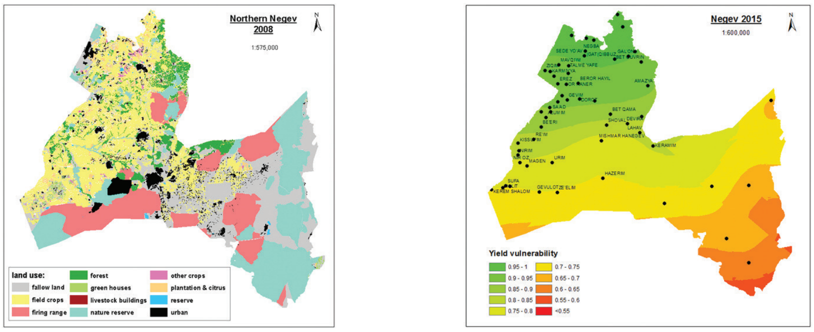


Figure 14: Model prediction for (a) the land use of the Negev in 2015 and (b) the ratio of wheat yield as predicted by the model for 2015 (for the weather conditions and irrigation system as observed during 1990-2010 and extrapolated to 2015) and the wheat yield in 2015 as predicted for the non-drought conditions (source: ENSURE consortium)

Results with regard to vulnerability assessment using the ENSURE framework

Vulnerability gradually increases from north to south-east of the Negev and the system resilience is relatively low in the eastern part of the Negev, which, however, is sparsely populated and not used for agriculture. Investigation of the model demonstrates that investment in the irrigation network in the Jewish settlements is currently sufficient for preserving the robustness of the entire Negev territorial system. However, to cope with intensification of the drought phenomena in the Negev, Bedouin sheep-raising should change from traditional to modern and intensive forms. To conclude, the Negev's resilience to drought is currently high. Even if the drought develops further during the coming decades, this resilience could continue to remain high with the intensification of the Bedouin husbandry.

5.3 Ilia Prefecture, Greece

General introduction and setting

The Prefecture of Ilia (see Figure 15) covers an area of 2,681km2 that consists of 22 municipalities. The population of the Prefecture amounts to 193,288 inhabitants (census 2001). In proportional terms the Prefecture as a whole retains a population of productive age (i.e. 15-64 years of age) but has increasingly lost a younger aged population. The human resources and socio-economic structures in Ilia are bedevilled by the unilateral development of the primary sector; low competitiveness of the local agro-food products due to persistence of cultivation products with low yield owing to the subsidies coming from the Common Agricultural Policy of the EU; small size of agricultural lots; unemployment and low education levels; an ageing population, low GDP per capita, lack of public welfare facilities; lack of infrastructure to support the use of advanced technologies, etc.

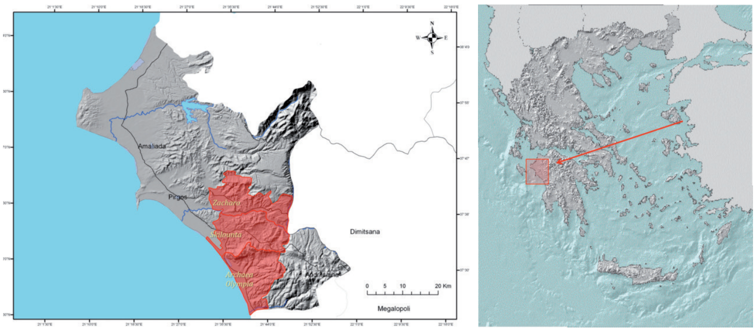


Figure 15: The Municipalities of Ilia Prefecture which make up the territory of reference for the vulnerability/resilience matrices on forest fires (source: ENSURE consortium)

Application of ENSURE methodology

In total 12 matrices (four per hazard) were constructed to assess the levels of vulnerability/resilience of the ecological, built, production and social systems in Ilia for seismic, forest fire and flood risks. Each group of matrices covered a different number of municipalities, depending upon the nature of the hazard. Here, though, comments will focus on the results of the assessment of vulnerability to forest fires, to show more in depth the application of the ENSURE methodology to this hazard. The reason for such choice is also the relevance of the recent 2007 fires that severely affected the entire area and which were considered as the reference impact for the appraisal procedure. The municipalities of Archea (Ancient) Olympia, Skilounta and Zaharo have been selected as the study area, given their centrality in the evolution of the event.
With respect to mitigation capacity, the natural environment in the study area displays a high level of vulnerability (see Figure 16). This is because maps of both vegetation flammability and areas particularly prone to fire already existed, but mitigation methods like integrated detection systems and monitoring staff were clearly inadequate in 2007. No risk mitigation planning existed and hazard knowledge was not incorporated in both building rules/practices and land use plans. The social system, instead, displayed higher mitigation capacity, thanks to forms of individual preparedness and availability of small scale mitigation resources, to media campaigns that informed inhabitants about forest fires risk, and to contingency plans developed and implemented by fire fighters.

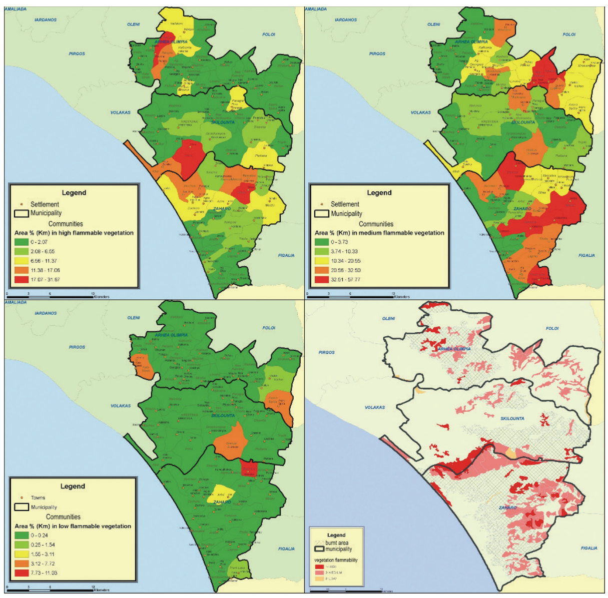


Figure 16: Vegetation flammability in the entire Ilia Prefecture (source: ENSURE consortium)

As for physical vulnerability, the scattered built pattern typical of the coastal zone, the relatively deep mean slope of rural settlements, and the presence of the important archaeological site of Ancient Olympia are all factors that substantially increase the exposure and vulnerability of the built environment. Similarly in both Archea Olympia and Zacharo roads pass through zones characterized by flammable vegetation (see Figure 17).

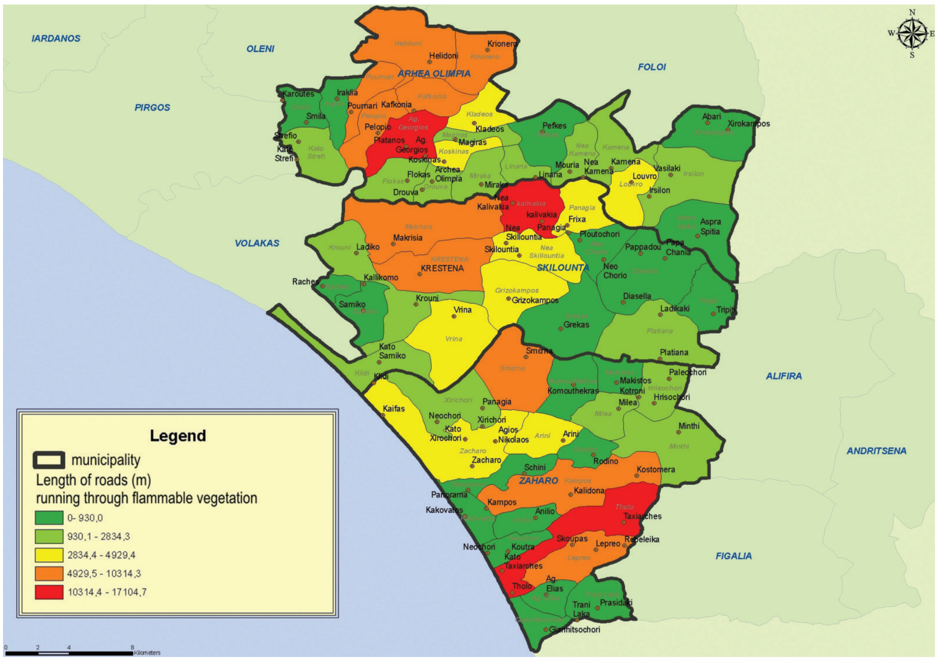


Figure 17: Length of roads running through flammable vegetation in the forest fires study area (community level) (source: ENSURE consortium)

With respect to systemic vulnerability, a relatively high level of vulnerability was evidenced for the built environment. Although, in fact, public facilities and equipment like movable devices are available, and travel time for fire-fighting vehicles is short, it is the scattered pattern of buildings and the low quality of signs that increase vulnerability. The coping capacity of the social system proved to be significantly reduced from structural impediments, such as: low to medium efficiency in information management, infrequent and too informal training of local fire fighters volunteers, and population ageing. These conditions were exacerbated by insufficient crisis management, due also to overlapping responsibilities among institutional agents.

Even though too little time has passed to be able to fully appraise the resilience of the Prefecture in the face of the recent disaster, some aspects have been highlighted. Among the factors that must be considered for the natural environment, the type of species used for reforestation is one important parameter. The data though are incomplete, while an available study for Archea Olympia suggests that in this municipality endemic species were used. As for the built environment, the structure of land ownership constitutes an obstacle in applying basic mitigation measures that lead to recovery, such as vegetation clearance in fragile zones at the small scale. But what is more important is the fact that both sharing among stakeholders and integration of physical reconstruction with healing processes are assessed as rather low. On the other hand, as a positive aspect, the relative compliance with norms prohibiting development in burnt areas can be observed, probably due to the public opinion attention on the case given the enormous devastation provoked by the fires.

Regarding the resilience of the social and economic systems, availability of private funds in the form of donors cannot balance the lack of economic means for tackling structural impediments. Furthermore, the aging population, the negative growth of the population as a whole, and the dependence on unskilled labour mainly in agriculture constitute important barriers to the resilience of the community. Positive aspects, though, are the low criminality rate and limited social conflicts.

What makes the overall eco-human system extremely vulnerable is the dependency of the social/economic system on the ecological and vice versa. Economic as well as social viability of the communities in Ilia depend on vigour and in any case satisfactory condition of forest and rural ecosystems due to the exclusively agricultural and tourist orientation of local economies. Conversely, protection of the ecosystems from the various threats (drought, fires, clearances, land use changes, frost, etc.) depend on human action and institutional measures.

	System	Aspect	Parameters	Criteria for assessment	Descriptors	weight	score (1=high; 5=low)	Application to Ilia case study
Natural environment	Natural Hazards	Are natural hazards known and mapped?	Hazard maps availability	Maps of areas prone to fires; map of inflammability of vegetation	yes/no; quality as judged with respect to international standards	1	2	YES but not in relation to phytoclimatic and land use maps
			Do hazard assessment consider climate change?	Binary	Yes/No	0,5	2	NO
		Is available knowledge updated?	Hazard maps updating	Frequency of updating	Every 2 years and after each event/rarely	0,5	2	NO
		Are hazards monitored?	Existence, distribution and quality of monitoring networks	Technical monitoring systems linked to operation centre	Yes/No	1	4	YES, daily during the fire prone season
				Permanent staff displaced in critical areas for direct monitoring and immediate intervention	Yes/No	0,5	2	In few cases
		Are monitoring systems connected to forecasting modelling systems?	Availability, quality of early detection systems and models	Binary; quality of early detection and propagation estimation models	yes/no; models tailored to the geographical context/not tailored	0,5	2	Detection systems were available before 2007, but according to the view of the Forest Head officer these were useless. The fire brigades even stated such systems did not exist
		Structural defence measures	Existence of defences for breaking the fire lines	Binary	Yes/No	1	4	Defences for breaking the fire lines have been identified (see parameter in the social system part)

Table 4: Mitigation capacity in Ilia 2007 forest fires – the natural environment system: an example of the ENSURE matrix (source: ENSURE consortium)

Chapter 6 Temporal and spatial cross-scale relationships: proposals on how to make the framework dynamic

As suggested by Wilbanks and Kates (1999: 601), «Improving the understanding of linkages between macro-scale and micro-scale phenomena and processes is one of the overarching intellectual challenges of our age in a wide range of sciences». Linkages and connections among different vulnerability facets, and interdependencies among systems resulting in sometimes surprising vulnerabilities or resilience factors, can be observed in back analysis, but are extremely difficult to recognise before an event occurs (Fekete et al., 2009). Therefore, it is clear that tackling cross-scale relationships among matrices and parameters pertaining to different matrices proved to be particularly challenging.
A first type of interconnection exists between indicators within the same matrix (see Figure 18). In general terms, it can be assumed that social agents in various forms may have a direct or indirect, strong or loose influence on all other types of vulnerability. Social vulnerability may worsen the vulnerability of natural systems (for example the decision to change the type of vegetation coverage for economic profitability may induce slopes instability or encourage the plantation of more flammable species), of the built environment (because of lack of compliance with norms and state of the art techniques), and of critical infrastructures (determining not only their construction quality, but also to what extent they are privatized, whether or not managing companies are controlled, coordinated by public bodies).

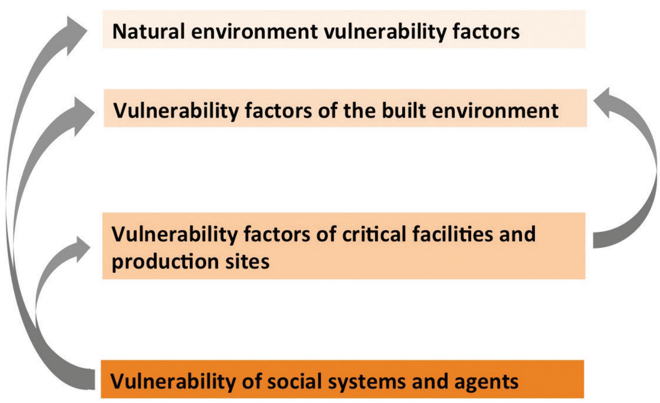


Figure 18: Relations among indicators within the same matrix (source: ENSURE consortium)

As for the time scale across relationships for example, what is decided in the period before the impact has clearly direct consequences on physical and systemic vulnerabilities (see Figure 19). Differently, the resilience of the system is not dependant only on pre-event decision, as emerging positive capacities may arise from society and territories in sometimes unexpected ways, difficult to fully envisage before the event. In this regard, while recovery and reconstruction clearly pave the way for creating or eliminating vulnerabilities and are therefore always part of "mitigation" to the next, future, extreme event, the relation between mitigation and resilience is not necessarily so linear. Resilience, though, has to do with the expected level of damage and the extent to which places and communities are disrupted in the aftermath of the event.

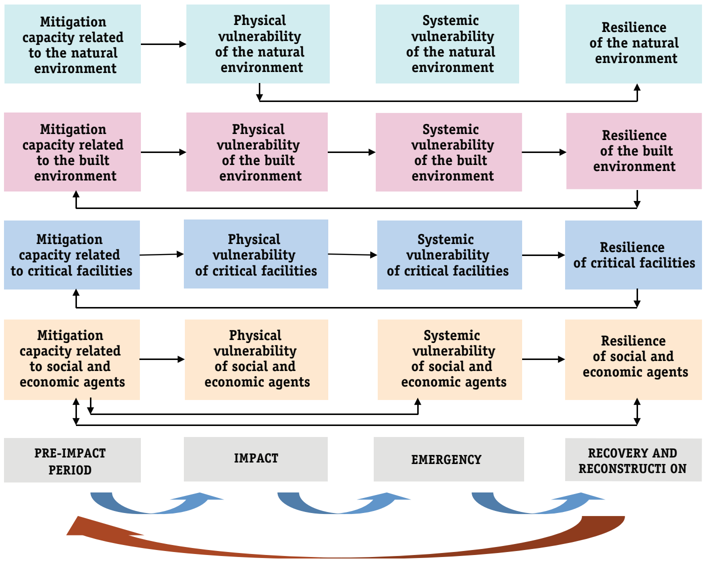


Figure 19: Relations among indicators across the set of matrices (referred to time-scale levels) (source: ENSURE consortium)

How to play on such interconnections in prospective terms, before an event strikes, seems at the present state of the art impossible (or perhaps even counterproductive from a conceptual viewpoint). Still, the validity of a vulnerability and resilience assessment requires the understanding of such connections to avoid misleading results that do not take into account how the various factors interact in a real setting.
What the ENSURE project has proposed is to condition such relations among indicators across temporal and spatial scales to a predetermined scenario. In this case, only some relations and connections that are recognised as relevant will be fully appraised. Any other connection or link possible in theoretical terms, but not observed in the scenario, will be "switched off" and not examined in that particular case.

An interesting dynamic adaptation of the ENSURE framework to the case of forest fires in the Mediterranean regions (see Figure 20) has been attempted by one ENSURE partner, searching the most relevant linkages between actors and objects in the wildland-urban-interface (WUI), defined as areas where urban lands meet and interact with rural lands (Lein and Stump, 2009). In the example in Figure 20, interactions among stress → physical damage → systemic vulnerability → response to losses → assumed capacity to recover have been envisaged in Southern Mediterranean regions, leading to the recognition of consequently relevant relations among indicators across time and space. As for temporal linkages, for example, a demographic decrease in the rural areas may lead to the abandonment of arable areas and their subsequent conversion to woodland, as occurred in Portugal and Greece (Pereira et al., 2004; Xanthopoulos, 2003). This relation can be abstracted by the agent population modifying the object land use and flammability (see arrow 6 of Figure 20). In a similar way, the agent governance (usually present at macro- and meso-scales of the pre-event phase) was found to shape physical vulnerability at the micro-scale via the agent population and their interaction with the built objects and natural environment. It was observed that residential risk management decisions (arrows 7 and 8 of Figure 20) are made in reference to institutional incentives provided by the existence of public fire suppression (arrow 3 of Figure 20). If residents believe that fire fighters have the capacities to protect local homes they are less likely to implement measures to reduce home ignitability (Colins 2005).

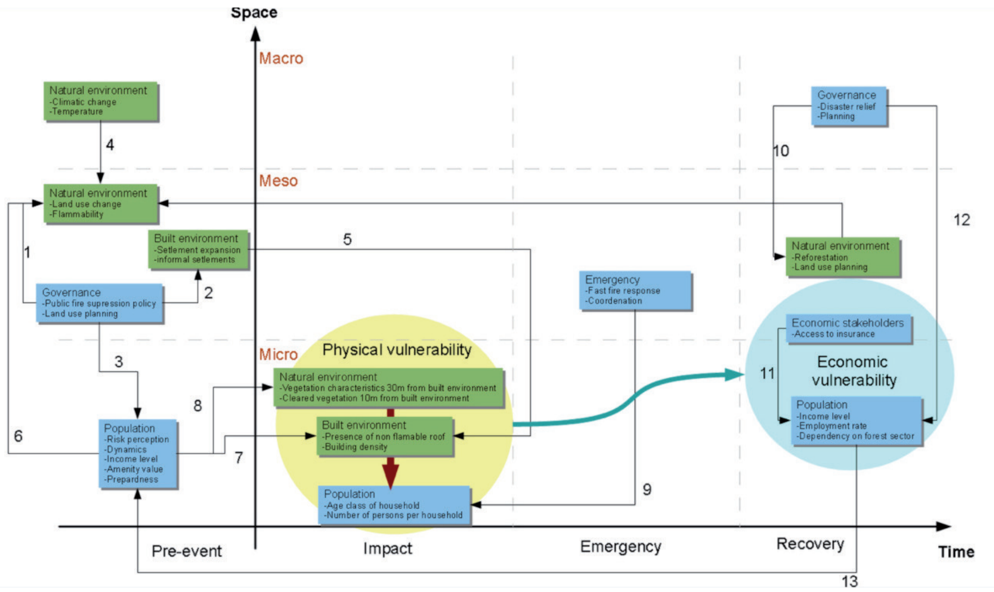


Figure 20: Conceptual framework for the assessment of vulnerability of people and build environment to forest fires in the WUI (source: ENSURE consortium)

Chapter 7 Final assessment of the framework and future potential developments

The application of the ENSURE framework to the various case studies has been certainly a challenging task, given its inherent prototype character. Yet, such an exercise has helped to identify a number of advantages of the methodology as well as a number of limiting issues where further improvements are required.
The ENSURE methodology represents a comprehensive assessment of vulnerability, incorporating - as it does - four types of inter-related vulnerability, a consistent set of systems and a large range of parameters. It is possible, using such a methodology, to form a comprehensive view of vulnerability to different types of hazards in a particular, multi-hazard area. The methodology captures parameters relevant to various spatial scales and administrative levels. Its application might lead to more efficient ways of carrying out trans-boundary policies for coping with extreme events.
In several cases, vulnerability values varied enormously between the pre- and post-disaster stage, confirming in fact what has been stated in sociological literature since a long while (Bankoff et al. 2004, Cutter, 2003; Gallopin, 2006). The differences in vulnerability in the different stages of the disaster cycle need to be better understood and addressed by emergency responders and others.
One of the main advantages of the ENSURE methodology is that it may be used to formulate assessments ranging from a rapid, desk-based, partially quantitative/partially qualitative assessment of vulnerability through to a fully analytical and research based assessment employing a larger range of quantitative data (mixed with some qualitative data). This potential versatility is considered as an extremely useful quality given that it allows preliminary screening assessments to be made which may then be followed up by more detailed and penetrating assessments as necessary.
Another advantage of the methodology is that it is characterized by transparency of the assessment process. The assumptions, simplification, limits and uncertainties of the method are explicitly declared. In addition, the methodology is flexible enough to enable future developments in research and practice that can be incorporated without making significant changes in the whole structure of the method; and it also supports advancements in designing precautionary measures.
In vulnerability and resilience assessment in multi-hazard environments, integration and synthesis of the distinct groups of matrices which correspond to the selected hazards (i.e. forest fires, floods, earthquakes) has not always been possible, because the analyzed spatial levels were not always coincident, though overlapping. This is hardly surprising and should not be considered as a shortcoming, since it has been the inevitable outcome of diversified exposures. Furthermore, the methodology has proven to be ideal for comparing vulnerability of the four carrying systems (the natural, the building, the infrastructures and the social) at a specific stage, as well as for comparing vulnerability of a specific system at the distinct stages. However, it does not offer a formula for integrated assessment of vulnerability of all systems during a full disaster cycle, a task that can be set to be a big future challenge.

7.1 Availability and quality of data

The framework requires a significant amount of data when the operator chooses to go beyond the desktop based approach. Such a task can be problematic in terms of time and cost. However, it has to be recognised that a penetrating analysis of vulnerability is almost bound to require a significant amount of data.
Such a requirement is accompanied with two limitations. First, data may not exist to allow a parameter to be assessed and therefore a data gap may emerge in such cases. Non-existence of data may be related to limited availability of data according to the targeted geographical scale. It may also be related to significant time laps due to the source of data (i.e. censuses providing data in 10-year periods). Second, in many instances the parameters at hand are of a synthetic nature and have been built on specific data combinations. Therefore, possible data gaps may weaken the overall elaboration of such parameters.
But, despite these limitations, what is important here is that the methodology allows the operator to record, and then use when assessing vulnerability, the quality of the data used to score parameters. This feature also allows areas where data quality needs improving to be highlighted for further action. In this respect, limited availability and/or synthesis of data can be a strength, in that it allows for data improvement and better targeting in subsequent rounds of vulnerability assessment.

7.2 Scoring and weighting

The ENSURE framework seems to be flexible for different paths of interpreting and applying the provided parameters, also in relation to different geographical contexts characterized by different features. It allows vulnerability scores to be allocated at different levels of aggregation (from the scores related to each parameters to the final score of the systems) and, consequently, to compare physical or systemic vulnerability of different systems or different areas within the same system, or to identify the main factors contributing to make an element or a system vulnerable, in order to define adequate mitigation measures.

The scoring and weighting system is a core aspect of the framework. Given the current state of methodological advancement, different scoring alternatives have been explored in dealing with the various types of hazards across the three main case studies. Such a variety allows for a much needed flexibility when it comes to the complex pragmatics of empirical assessment.
On the other hand, lack of harmonization, as well as the inconsistencies of synthesizing quantitative and qualitative parameters in different ways, exhibits some limitations. Each weight and score also requires further definition to ensure consistent use across operators and among different types of hazards. Moreover, it may sometimes be that one indicator is the combination of several other parameters, which can lead to some difficulties if the system is not well defined or data availability or quality is low. Therefore there is still room for further experimentation regarding the theoretical aspects of our methodology.

7.3 Specificity of context and geographical scale

The framework has helped to identify how parameters may differ not just for different hazards but also within different European contexts. For example, parameters such as lack of safe exits routes from underground facilities or flooded buildings were found to be largely irrelevant for Ilia in the case of flash floods. Thus many of the parameters identified for floods in different European contexts - e.g. urban areas in the UK and Germany - proved to be irrelevant in the case of rural Ilia. Such a conclusion reinforces the fact that floods (and alternatively any hazard), their impacts and institutional arrangements for dealing with them are context specific. Another issue has to do with geographical scale. Assessments may be conducted at a variety of scales and care needs to be exercised when comparing assessments among different scales. This problem has been highlighted in the matrices just as there have been spatial - as well as temporal - variations of parameter values and vulnerability scores. Each single matrix features parameters which are different in their scale of reference. Some parameters are homogenous for the whole area under consideration (e.g. institutional parameters); other ones diverse enormously from one building to another, from one village to another, etc. The scale problem has been adequately dealt within each hazard case, and in all cases a change in scale was explicitly made clear. On the other hand, as discussed in Chapter 6, cross-scale temporal and spatial relations are still a matter open for future research. In summary, given the prototype character of the framework, it cannot be simply given to potentially interested stakeholders leaving them "alone" in the application of the framework and the individual matrices. A number of intermediate steps must be followed in order to use it at best and none of them can at the moment be "standardized". Therefore, in a further evolution of the methodology, a sort of discussion and participatory approach should be taken, involving different stakeholders to understand with them for what specific purposes, how, to what extent, and with which changes the methodology can be successfully applied. On the other hand, getting acquainted with the methodology requires some time and practice. Guidelines to help follow the methodology may certainly help, but as stated by in medicine, history/human sciences (and we may add in vulnerability and resilience assessments), «the elastic rigor – to use a contradictory phrase – of the conjectural paradigm seems impossible to eliminate. Nobody learns how to be a diagnostician simply applying the rules» Ginzburg (1980: 28). The possibility of adapting the matrices to allow them to be applied through automatic procedures within a decision support system (DSS) based on use of GIS also deserves to be investigated.

7.4 Developing a common framework: the challenge for interdisciplinary collaboration

Developing the framework required not just simple collaboration or focusing on a given task or problem, but actually defining and designing the contours of the problem itself (what Eigenbrode et al., 2007 define as the third and more difficult level of "interdisciplinarity"). In fact we had to state what resilience and vulnerability meant for us and how we intended to convert the agreed upon interpretation into a way of measuring and assessing (see Winograd, 2007). As stated by Lélé et al. (2005), the readiness to this type of collaboration and coordination requires, together with the acceptance of the other, the willingness to cross disciplinary borders. It implies much more the capacity to select and simplify relevant knowledge in a form useful for the collaboration, rather than the specific field of expertise or personal curriculum.
There was an agreement among ENSURE partners that the framework constitutes a significant achievement for the project, which provides the possibility for each type of expertise to locate itself within a larger and more comprehensive context. At the end, engineers will continue studying what are construction features that make buildings and networks more or less vulnerable to earthquakes, floods or forest fires; in the meantime though, they will understand that the "root" causes and the drivers of such physical weaknesses have to be looked for elsewhere, in the legislative and institutional arrangements, in the capacity of governments and administrations to implement and achieve compliance with building codes, land use norms and regulations. Volcanologists, seismologists, hydrologists will certainly continue to attribute high relevance to the availability of hazard maps; in the meantime though, in having to assess also the quality of produced maps, they will consider to what extent those maps are fit to support planners and decision makers in land use choices, relocation programmes, development and redevelopment of urban areas and infrastructures.

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Annexes

Annex 1: Other ENSURE case studies

Municipality of Corvara, Italy

General introduction and setting

The area studied forms part of the Municipality of Corvara, which is located in the Upper Badia Valley (Alta Badia). This is a mountainous area, characterized by a high flow of tourists both in winter and in summer. From the geomorphological viewpoint, it is characterized by very high relief energy and lithotypes which can be susceptible to various types of slope movement, making Corvara a real laboratory for landslide studies and suitable for a risk study, as it is possible to correlate vulnerability elements with hazard elements. With reference to the proposed ENSURE methodology, both the meso-scale and the micro-scale were used; the former was used regarding the overall study area where a semi–quantitative assessment was made, while the latter was used for the special case of the Corvara landslide (see Figure 21). The 4-matrix vulnerability-analysis of the ENSURE methodology has been applied to the Corvara case study in order to verify both the applicability of the methodology in an area affected by landslides, to test its validity there and the proposed improvements or highlighting of problems.

Figure 21: The Corvara landslide (source: ENSURE consortium)

Application of ENSURE methodology and results in regard to vulnerability

The "Mitigation Capacity" matrix is the most applicable to the Corvara landslide - hazard and risk plans in the vulnerability framework. This is because those plans are the best measure to verify the capability of a municipality to cope with natural hazardous phenomena and trying to prevent their negative effects on the natural and built environments. Good alert and civil protection systems may develop only if those plans exist. The main problems found are essentially the necessity to constantly update those plans and to cope with the deterioration of mitigation works, and sometimes also problems of monitoring systems.
The "Physical Vulnerability: vulnerability to stress (hazard)" matrix, works properly if a small area is considered, since quantification of both impact energy and strength of structures and infrastructures can be reasonably carried out. This is not feasible for a wider area like a municipality, and the Corvara case study showed how a more qualitative approach might give "more usable" (and more economically affordable) results.
Regarding the "Systemic vulnerability: vulnerability to stress (hazard)" matrix within the Corvara case study little has been done by the community to assess the capacity of structures, infrastructures and systems to recover. Nevertheless, we suggested again a more qualitative "degree-of-functionality" assessment, certainly more applicable at the meso-scale. Moreover, we stressed the need to have the best possible picture of past events and damages (also taking advantage of experience from other areas) in order to forecast what degree of functionality can also be expected in the future. Qualitative results from the "physical vulnerability assessment" matrix have demonstrated usability for forecasting losses (direct and indirect) that may affect the economic system in a semi-quantitative way.
The "Resilience: response capability in the long run" matrix deals partly with something that has not been considered in Corvara (i.e. Civil Protection Plan), but whose effectiveness depends a lot on the existence of hazard and risk plans which we identified in the "Mitigation Capacity" matrix. While the value of a Civil Protection Plan depends at first sight on the availability of structural defences and on the preparedness of people (at all levels), it surely depends also on the presence of well executed and updated hazard and risk plans. Therefore the "Resilience: response capability in the long run" matrix leads back to the "Mitigation Capacity" matrix along the timeline axis, showing that "updating of knowledge" is the most important parameter to work on.

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Tigray region, Ethiopia

General introduction and setting

Climate change and variability acutely affect rural livelihoods and agricultural productivity, yet it is just one of many stresses that vulnerable rural households have to cope with. Standard macro-scale assessments of climate scale can hide enormous variability concerning livelihood vulnerability within regions and districts. Consequently, the vulnerability of agrarian communities to climate change and variability was investigated across 34 agricultural-based districts in the Tigray region, Northern Ethiopia (see Figure 22).

Application of ENSURE methodology

Following the ENSURE methodology, 23 biophysical and socioeconomic indicators were considered to reflect the effects on the natural environment, infrastructure, production sites, and on the social system. For the natural environment, data was collected on extremes and changes in climate conditions, irrigated land and vegetation cover. For infrastructure and production, we used data on physical infrastructure and small-scale farming. The social system was represented by data on rural population, landless population and illiteracy. Finally, response capability was depicted by wealth indicators like livestock ownership, quality of residence, application of technologies (fertilizer).
Data were collected via the Central Statistics Authority in Ethiopia and Spot vegetation ten-day composite NDVI were acquired from the Flemish Institute for Technological Research NV (VITO), Belgium. The classic statistical technique of Principal Component Analysis was applied to generate weights for the various indicators in 34 districts.

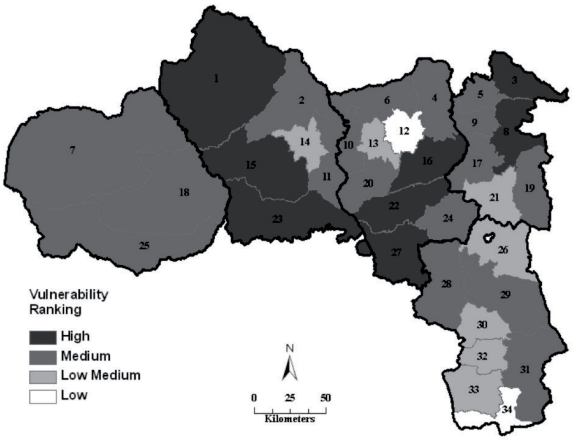

Figure 22: Overall Vulnerability Indices across the farming districts in Tigray Region (source: ENSURE consortium)

The spatial results of the study revealed that the districts deemed to be most vulnerable to extreme events and to climate variability overlap with the most vulnerable populations (see Figure 22). The farming communities most exposed to climate change and variability also have a relatively low capacity to adapt. The results further show that vulnerability to climate change and variability is intrinsically linked to social and economic developments. The spatial scale at which the assessment was conducted provided a means for evaluating the relative distribution of vulnerability at a district level, making our research the first in the country at lower scales and higher resolution.

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City of Istanbul, Turkey

General introduction and setting

As a metropolitan city, Istanbul shares with the majority of fast developing areas rapid urbanization, illegal housing supply, and the increasing gap between socio-economic classes. In addition to these global trends, the city is located in an earthquake hazard prone area. The present vulnerability of Istanbul is the result of a long-term process and its roots can be traced to the policies set in the 1950s, focusing on the economic development of the Istanbul region.

The plan of Istanbul developed by Henry Prost (between 1936-1950) established industrial areas right in the centre of the city. In the 1950s residents started to move to the peripheries, pushed by the decreasing quality of the urban environment. New migrants have now moved into the vacated old urban fabric located in the heart of the city. As central and local governments were unable to fulfil the residential needs of large numbers of immigrants, they built their own houses illegally, and mostly situated in risk zones such as water basins, alluvial soil and land-fill areas (see Figure 23). As a result of these trends, the city became more vulnerable to hazards, because of the low quality dwellings, increased population density and industrial production in between the residential areas. Since the 1980s, driven by new regionalization policies, industries have started to move to Kocaeli and Adapazari in the Eastern part of the region and to Kucukcekmece in the Western part. Especially in the Kucukcekmece district, the establishment of formal and organized zones has created potential for na-tech hazards. In the case of an earthquake, the severe stress provoked could break pipes and release hazardous and toxic substances. At the same time, the rapid urban expansion of the city through the Western and Eastern parts has placed great pressure on natural resources, especially on underground water reservoirs.

Application of ENSURE methodology

Istanbul is a composite of many diverse and interrelated systems as any other metropolitan city. To apply the ENSURE methodology, the most complex and interrelated part of the city which is the Western part comprised between the historical peninsula and the Kucukcekmece district was chosen as the case study area, as it provided possibilities to evaluate both resilience and vulnerability as well as systemic vulnerability and vulnerability to na-tech hazards. In addition to the characteristics mentioned above, another reason for choosing this area was the presence of the biggest hospitals in the City.

In this case study the ENSURE methodology was applied by focusing on systemic failures in the event of an earthquake occurring. The study area displays a high level of vulnerability, not only because of the soil quality but also the high vulnerability of the interrelated parts of the system. As an example, hospitals located in the most populated and dense areas can be considered. Their physical vulnerability is increased by being located in areas which may be subject to amplification of seismic waves. From a systemic perspective, accessibility is crucial especially during the emergency phase of a disaster. Roads connecting these major health services to other parts of the city are expected to be blocked by collapsed buildings. Water supply is another crucial issue for health facilities with respect to sanitation. Although hospitals possess their own water reserves, considering that disaster response and recovery time may be prolonged, it can be assumed that the reserves may be used up within a limited time period. Moreover, several power cuts are expected to occur in the event of earthquakes in different parts of the city that may cause interruptions also in the functioning of health equipment as well as in the water pumping system. This example suggests that micro-scale mitigation activities need to be completed at the territorial scale by focusing on vulnerabilities of the components, and vulnerabilities raised due to interconnectedness of those components, to understand both vulnerability and resilience of the system, and consequently, to propose the most suitable provisions.

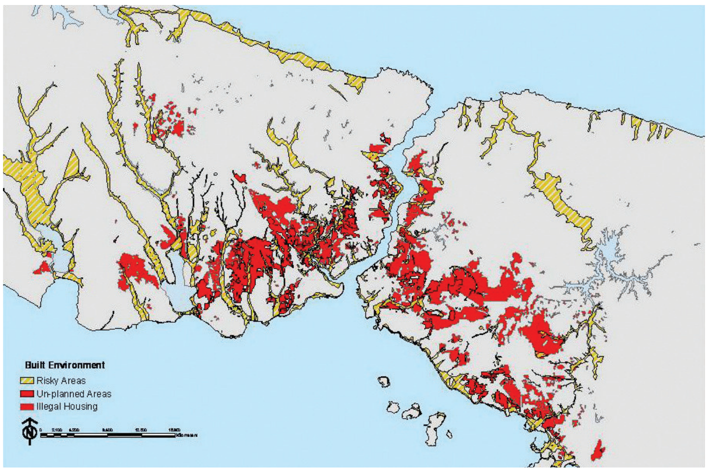

Figure 23: Overlay of risky areas and un-planned areas in Istanbul
(source: ENSURE consortium; data provided from Istanbul Master Plan Reports, 2009)

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Annex 2: The ENSURE e-learning tool on vulnerability assessment: http://ensure.metid.polimi.it

The ENSURE e-learning tool on vulnerability assessment is organized as a course without external assistance and has been developed to reach and involve students, practitioners and other technicians as target users. However, it also is an additional dissemination activity of the ENSURE project in general. Therefore documents and activities offered on the e-learning platform are generally aimed at all interested users.
The learning path has been obtained from the ENSURE project contents and results and offers a sequence of themes, theories, methodologies, tools and case studies which the users can browse and experience. The website also offers activities to auto-test the achieved learning outcomes.
The choice for the contents and the design of the e-learning tool required a careful review of all project documents produced and specific work to adapt them for use on a website. This adaptation was necessary because of the complexity itself of the subject matter – vulnerability and resilience to hazards – and because of the need to simplify such complexity into a clear and useful learning path.
With this in mind, we tried to design a website where the contents are interesting and appealing to many users, offering a variety of examples and case studies developed through a multimedia approach (texts, hypertexts, images, videos, links to other websites) and embracing interdisciplinary approaches, theories, methodologies and tools.
The e-learning tool aims at introducing users to the vulnerability and resilience assessment model proposed in the ENSURE project, specifying procedures, criteria and parameters to make it operable within a given territorial or cultural context. Case studies at local scales and within regional contexts complete the picture, proposing an approach for better understanding the articulated nature of the concepts of vulnerability and resilience (i.e. physical, economic, cultural, social and systemic) at different spatial scales (regional and local), useful for exploring the integration and connections of different types of vulnerability and resilience and for developing assessment processes and future scenarios.
The learning menu is composed of four main modules. Two learning modules are devoted to theoretical and methodological issues related to Vulnerability and Resilience Concepts and Vulnerability and Resilience Assessment. The third module is devoted to the analysis of case studies and the last one contains final activities and exercises referring to the whole proposed learning contents. In each module the user can find some brief introductory text, files containing the specific learning contents, exercises or examples useful to check the learning level obtained, and links to the ENSURE final project documents, where it will be possible to find insights and details about the items discussed in the project. Each module is enriched by a selection of bibliographical references and links to other websites to address users interested in deepening their understanding of the theory and practice of vulnerability and resilience assessment.

Figure 24: The ENSURE e-learning tool Home Page

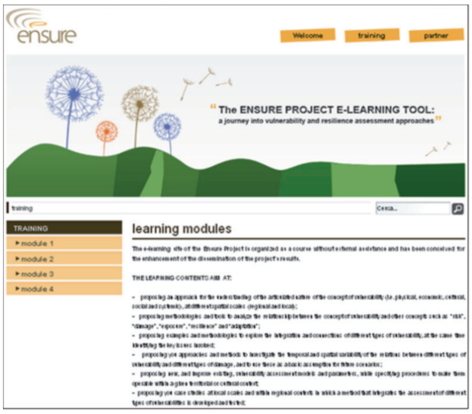

Figure 25: The Introduction Page to the ENSURE e-learning tool

Annex 3: Facts about the ENSURE project

The "Enhancing resilience of communities and territories facing natural and na-tech hazards" (ENSURE) project was a Specific Targeted Research Project funded by the European Union as part of the 7th Framework Programme for Research and Technological Development.

Objectives

The overall objective of ENSURE was to develop a new methodological framework for Integrated Multi-Scale Vulnerability Assessment. The framework is based on a comprehensive, integrated and interdisciplinary understanding of how mitigation strategies can be improved in the future. The framework will contribute to a better understanding of how human losses, economic damage and social disruption due to extreme events can be lowered.

Expected Impacts

ENSURE has contributed to an improved analysis of vulnerability for improving the resilience of communities.

Specific impacts have been to:

1. provide support for policy decisions with key stakeholders, at various scales, relating to prevention measures and plans in order to minimise damage from natural disasters;
2. present, through the Integrated Multi-Scale Vulnerability Assessment, a feasible tool to improve communication with local communities in the process of raising risk awareness, on technological expertise, and for a better understanding of social and cultural factors to help increase public involvement;
3. understand adaptation and resilience factors, and system responses, which help to minimize risks from natural and human-triggered technological disasters; included within this is the ability to assess the vulnerability of strategic facilities and infrastructures;
4. improve our understanding of environmental vulnerability to some natural disasters, and particularly to some of the secondary consequences, e.g. due to the interaction between vulnerable assets, wrong risk management practices and the "natural environment".

ENSURE involved 10 partner institutions from France, Germany, Greece, Israel, Italy, The Netherlands, Switzerland, and the United Kingdom. The project started on 1 June 2008 and finished on 31 May 2011.

Scientific partners:

BRGM

Harokopio University of Athens

International Institute for Geo-Information Science and Earth Observation

Middlesex University Higher Education Corporation

Politecnico di Milano

Potsdam Insitut fuer Klimafolgenforschung

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