	ENSURE PROJECT *Contract n° 212045*

ENSURE E-LERNING TOOL

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Organizing knowledge for vulnerability and resilience assessment: the set of matrices developed within the Ensure project

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Area "Environment"
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Reference reports:

Del. 4.1: Methodological framework for an Integrated multi-scale vulnerability and resilience assessment (chap.2.3 and Appendix 1)

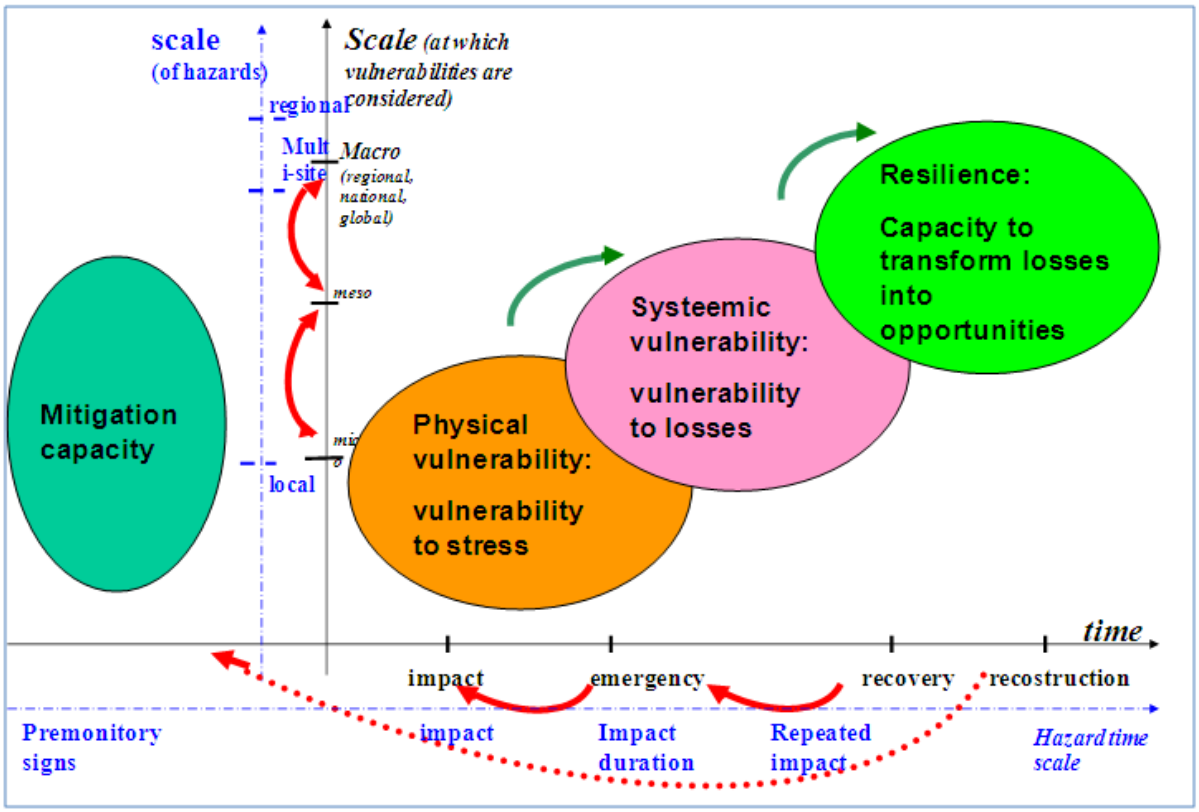
Table of contents

See references in ENSURE Del4.1

1 Short description of the set of matrices comprising framework

In this paragraph the ellipsoids content as represented in figure 1 will be discussed in detail. Actually each ellipsoid is translated into a set of matrices as will follow in figure 2.

Figure 1: General representation of the integrated framework to assess vulnerability and resilience across time and scales



In each matrix vulnerability indicators are proposed, taken from literature, ongoing and past research carried out by the Ensure team.

In the first set of matrices, the capacity to mitigate is addressed; this means concretely that the vulnerability of the natural environment, the characteristics of the hazard are known, mapped and monitored appropriately. With respect to the vulnerability of objects and artefacts what is checked here is whether or not vulnerability assessment have been carried out and taken into consideration in planning and risk prevention policies; in the case of critical facilities, not only the awareness of systemic vulnerability is addressed but also the capacity to reduce it in ordinary maintenance programs and anytime new facilities or replacement of existing ones must be conducted. With respect to agents, their awareness of existing threats and fragilities is assessed as well as their willingness/capacity to address them when the hazard does not seem to impede in any particular fashion and time has passed since the last catastrophic event.

In the second set of matrices, the physical propensity to damage of the natural environment, objects, critical facilities and people is assessed. All factors that may increase the potential damage are considered, including the possibility of enchained effects, both between natural hazards (like for example landslides triggered by earthquakes) or between natural and vulnerable built systems (like for example na-tech).

In the third set of matrices, the potential reaction to first level losses is addressed: secondary effects in the natural environment, like for instance lahars or debris flows consequent to fires denudating entire slopes is considered. With respect to artefacts, urban areas and critical facilities, the capacity to keep functioning despite some level of physical damage is evaluated, considering the interdependencies among systems and among components of vital systems. With respect to agents, the capacity to manage emergencies, to endure in time of limited facilities and restricted access to resources and markets is considered.

Finally, in the last set of matrices, the recovery potential is appraised. As for the natural environment the ecological resilience is referred to, particularly for those hazards like fire or drought that may significantly disrupt the natural environment itself with permanent damage. For buildings and cities, the capacity to embed the lessons learnt in the disaster while reconstructing artefacts and places is evaluated, as well as the capacity to couple the physical reconstruction with the symbolic one, accompanying the healing process of a traumatized social system.

Regarding the latter, access to resources for reconstruction, availability of good administrative procedures, fast delivery of compensation are elements that seemed particularly relevant to accomplish a resilient recovery. Fast access to compensation need not to be taken as an isolated indicator: the capacity to couple it to the control of how reconstruction will proceed and to what extent pre event vulnerabilities will be addressed is equally if not more important.

In this respect, but as a general consideration for all set of matrices, indicators should not be considered as standing alone. Some must be appraised in conjunction with others in order to draw a vulnerability and resilience assessment of a given area and environment.

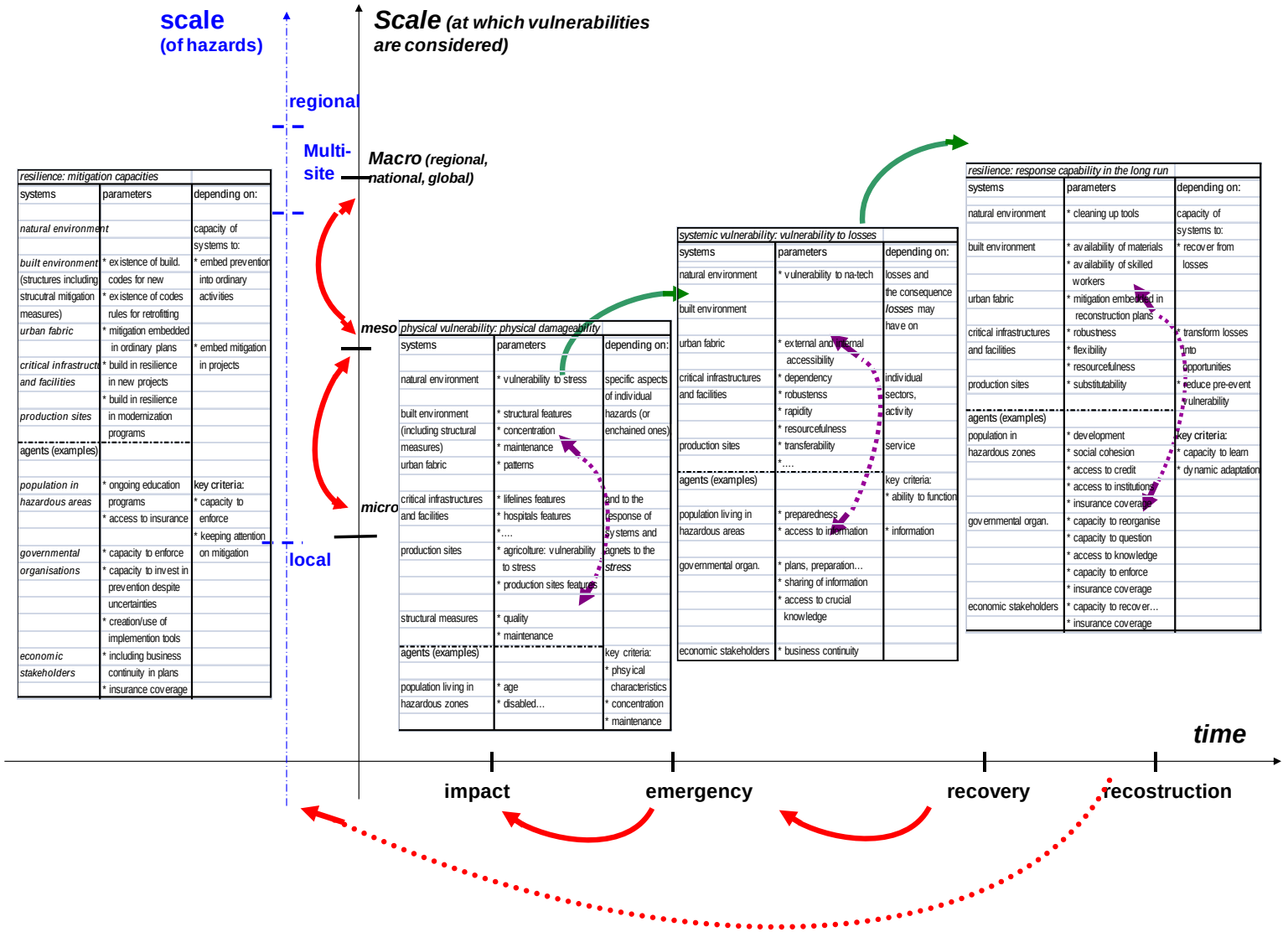


Figure 2: Ellipsoid translated into a set of matrices

Each matrix is in its turn divided in four parts (see figure 3).

1. The first relates to the natural environment. Indicators that can be found in this part respond to three main questions:

    a. Is the available knowledge, including its representation in maps, tables, and other forms, sufficient and sufficiently taken into account for decisions at each stage of the disaster event?

    b. Are enchained natural hazards considered in the hazard assessment. It should be noted that this and the previous question are not aimed at introducing surreptitiously hazard aspects into vulnerability analysis. Instead the point that is made here is that a given system is less vulnerable if hazards are well known, monitored and early warning systems are put in place when relevant.

    c. Finally there may be elements in ecosystems and in environmental settings that are particularly vulnerable to the consequence of an extreme event (this is particularly true for forest fires and droughts) or to the mitigation measures which are taken to protect some other systems (for example lava diverting systems to protect buildings and infrastructures that may lead to the destructions of forests).

2. The second relates to the built environment. In this part of matrices the following aspects are considered:

    d. Whether or not buildings have been built according to specific norms or to state of the art considering previous lessons learnt from past disasters. On the other hand, the position of buildings within hazardous zones has to be assessed. Clearly this is more the case of an “exposure” rather than a vulnerability factor.

    e. For public facilities, the question is if there are further vulnerability factors that must be accounted for, regarding internal machinery, assets, tools that are fundamental for the functioning of a given service.

    f. As for the urban fabric, the point at stake is whether there are some vulnerability factors arising at the urban scale, going beyond the simple sum of the vulnerability of individual buildings and infrastructures, and which relate to the shape of the urban patterns, to the relationship between open and built spaces and with accessibility.

3. The third regards critical facilities and production sites that are considered separately because of their importance in guaranteeing the survival of an urban system and for the well being of the potentially affected community. From a theoretical point of view they may be seen in conjunction with the vulnerability of the built environment, but from a practical and strategic perspective it makes sense to separate them. Critical facilities gain their prominence when systemic vulnerability must be appraised.

4. The last part is devoted to the assessment of social systems and economic stakeholders' vulnerability. Social systems' and agents' vulnerability has been considered with respect to three main sub-groups:

   g. Individuals vulnerability, related to the level of awareness and preparedness to both mitigate and face the consequences of an external stress;

   h. Institutions' vulnerability, in which all agencies and organisations that may have a key role in both disaster management and disaster avoidance are considered.

   i. Finally economic stakeholders, who, similarly to institutions, may have a leading role in shaping vulnerability, in creating coping capacity mechanisms.

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Comments/case study
Natural environment					
Built environment					
Infrastructure and production sites					
Social system (agents)					

Figure 3 Set of matrices comprising the framework

With the rather broad term of social vulnerability we address several components of societal coping capacity, ranging from individuals, to social groups, to communities, to organisations. Social vulnerability can be both physical and systemic, as people can be physically injured and harmed, but are also vulnerable to the lack of basic services, to the new conditions required by evacuation, temporary sheltering, et. In the same vein, organisations, like for example civil protection, can be harmed in their assets and personnel, or diminished in their capacity to react because of a variety of systemic failures, including the lack of coordination and collaboration among different agencies, problems in communication, problems in deciding about matters that hold significant juridical and moral challenges. An important distinction that has been introduced in WP2 is between social and human capital, intending that vulnerability of both should be appraised. For neither of these concepts universally accepted definitions can be found. Basically, we can assume that human capital refers to skills, dexterity (physical, intellectual, psychological) and judgement capacity, which may be lost during an extreme event; on the other side, social capital refers to the value of social networks affecting the productivity and capability of individuals and groups to cope and recover from an extreme event.

With economic vulnerability we refer to the response that economic sectors are able (or unable) to provide in the aftermath of an extreme event. Also in the case of economic vulnerability, both physical and systemic aspects must be considered. Economic assets can be physically damaged, but economic activities are clearly extremely vulnerable to interruption of transportation services, to deficient lifelines, etc.... Days without the possibility to work, to receive products or to send them to destination constitute a net damage measurable in monetary terms.

As can be seen in the previews figure 3, each matrix is organised in columns:

- The first identifies the system to be assessed;
- The second identifies the components of the systems;
- The third clarifies the aspects that have to be considered in the choice of the indicator/parameter that may better respond to the question, shown in the third column;
- The fourth and the fifth determines how indicators/parameters can be measured and assessed, upon what criteria and using what tools (maps, diagrams, scores).
- In the last column references are made either to a case study that was analysed in detail or to several cases that are relevant to the specific indicator at stake.

It has been decided to produce a set of matrices for each “hazard” (see figures 9 to 13). Methodologically it seemed useful to check to what extent the individual parameters in each set of matrices had to be differentiated upon the expected threat. In fact not only the

physical response to the stress is so to say “hazard” dependant. In each hazard different aspects related to monitoring and mapping must be considered, different specific mitigation measures must be taken before and after the impact.

This does not mean that a multi-risk perspective is not considered. Actually it is pursued in two ways. First, in each set of matrices the possibility of enchained events (hazards triggering other natural or technological threats) is fully appraised. Second, in applications (see WP5), a set of matrices related to the hazard threatening a given area can be used in combination. Results of applications to the test case studies confirmed that not only the physical vulnerability matrix is somehow “hazard specific”. An area, a community can be for example very well equipped and prepared for some events, while underestimate other hazards to which it is exposed.

2 Presentation of the entire set of matrices developed within the Ensure project

See matrixes in the following pages

First Matrix: Resilience: Mitigation capacity

System	Component	Aspect	Aspect Parameters	Criteria for assessment
Natural environment	*Natural Hazards*	Natural hazards identification and mapping	Hazard maps availability	yes/no; level of detail with respect to scale of decisions
		Available knowledge updating	Hazard maps updating	Frequency of updating
		Hazards monitoring	Yes/no; quality and distribution of monitoring networks	binary; expert judgement upon the quality of networks
		Integration of monitoring systems forecasting modelling systems	Yes/no; quality and reliability of forecasting models; match of monitored data to forecasting models	binary; expert judgement upon the quality of models; back analysis
		Structural defence measures	yes/no; quality of defences; state of maintenance	
Built environment	*Exposure and vulnerability of built environment*	Inclusion of vulnerability and exposure assessments in land use plans	Vulnerability assessment of exposed built stock	yes/no ; updating frequency
			Risk maps and scenarios, including enchained events	yes/no
			Vulnerability and exposure assessment considered in ordinary plans (example land use)	yes/no; mode of inclusion
	Rules and tools for risk mitigation	Availability, quality and efficacy of mitigation rules	Building codes/rules	yes/no; updated
			Traditional building practice based on hazard knowledge	yes/no; capacity to re-produce traditional techniques correctly
			Maintenance of building stock	yes/no
			Land use plans embedding risk mitigation and vulnerability reduction	yes/no; sectoral/comprehensive; specific/generic
			Implementation capacity	yes/no; frequency of inspections; trained personnel for inspections
			Integration to other measures (insurance)	yes/no
Infrastructure and production sites	*Critical infrastructures*	Existence of vulnerability assessments for critical facilities; level of consideration of vulnerability in programs regarding critical facilities	Vulnerability assessment of critical infrastructure	yes/no ; updating frequency
			Maintenance programs embedding mitigation	yes/no
			New projects based on hazard/risk assessment	yes/no
			Level of coordination among stakeholders	low/medium/high
	Production sites	Existence of vulnerability assessments for production sites; consideration of na-techs	Vulnerability assessment of production sites	yes/no ; updating frequency
			Retrofitting measures for existing production sites	yes/no
			New projects based on risk assessment	yes/no
			Na-tech explicitly accounted for in hazardous installations emergency plans	yes/no; expert judgement on quality
Social system (agents)	*People/individuals*	Evaluation of the capacity of individuals living in prone hazard areas of coping with hazardous events	Risk perception/ awareness	inexistant/average/good
			Individual preparedness	regarding specific self protective measures; regarding measures included in emergency plans
	Community and Instituions	Involvement of a community into decision-making processes related to risk prevention and mitigation, the capacity of institutions of improving risk awareness and the level of cooperation among different institutions in charge of risk prevention/ mitigation.	Participation in development and prevention/mitigation strategies	
			Education programs & media campaigns	
			Coordination and cooperation among institutions in charge of risk prevention/ mitigation	

Matrix to assess mitigation capacity

Second Matrix: Physical vulnerability: Vulnerability to stress (hazard)

System	Component	Aspect	Aspect Parameters	Criteria for assessment
Natural environment	*Natural ecosystems*	Fragility of natural ecosystems to hazard(s)	yes/no; parameters assessing specific response potential to different stresses	hazard specific
		Possibility of enchained effects due to the interaction of natural systems with the triggering hazard	yes/no; how natural ecosystems condition may worsen hazards' impact	hazard specific
		Vulnerability of ecosystems to mitigation measures taken during emergency	yes/no; how natural ecosystems may be impacted by mitgiation measures	hazard specific
Built environment	*Exposure and vulnerability of built environment*	Factors that make buildings, the urban fabric and public facilities vulnerable to the stress	Vulnerability assessment of residential buildings	hazard specific (though generally considering material, age of construction, structural features, maintenance conditions
			Vulnerability assessment of public facilities	hazard specific, considering also content (machinery, documents, etc.)
			Vulnerability of the urban fabric	hazard specific (though generally considering building density, height of buildings, morphology, etc.)
Infrastructure and production sites	*Critical infrastructures*	Factors that make critical infrastructures vulenrable (mainly lifelines	Vulnerability assessment of critical infrastructure	hazard specific; different for each lifeline
			Vulnerability due to physical interaction among lifelines	depending on location, age, degree of maintenance
			Vulnerability due to physical interaction with vulnerable buildings	depending on the type of damage that may affect or not lifelines
	Production sites	Factors that make production sites vulnerable (including na-tech potential)	Vulnerability assessment of production sites	hazard specific, though generally considering both structures, machinery, stocked material
			Vulenrability due to dependency on lifelines	depending on the degree of dependance upon external vulnerable lifelines
Social system (agents)	*People/individuals*	Factors that may lead to injuries and fatalities	Location with respect to vulnerable buidlings, roads, industrial sites	location in conditions where damage to structures may affect people
			Preparedness	hazard specific
			Specific sensitivity to hazards (smoke; ash, heat, etc.)	hazard specific
			Age; mobility impairment, other impairment	difficulties to comply with evacuation orders; difficulties in escaping
	Community and Instituions	Factors that may lead to large number of victims	Population density in vunerable areas	

Matrix to assess physical vulnerability

Third Matrix: Systemic vulnerability: Vulnerability to losses

System	Component	Aspect	Aspect Parameters	Criteria for assessment
Natural environmer	*Natural ecosystems*	Fragility of ecosystems to potential secondary effects of hazard(s)	yes/no; parameters assessing specific response potential to different stresses	hazard specific
		Possibility of enchained effects due to the interaction of natural systems with the triggering hazard	yes/no; how natural ecosystems condition may worsen hazards' impact	hazard specific
		Vulnerability of ecosystems to mitigation measures taken during emergency	yes/no; how natural ecosystems may be impacted by mitgiation measures	hazard specific
Built environment	*Exposure and vulnerability of built environment*	Factors that make buildings, the urban fabric and public facilities vulnerable to losses	Existance of public facilities and resources to face the emergency	yes/no; a scoring system can be developed depending on a hierachical assessment of resources relevance for emergency management
			Accessibility to vulnerable areas	redundancy; quality of roads; usability; expected travel time
			Accessibility to public facilities	existance in the area, redundancy; quality of roads; usability; expected travel time
Infrastructure and production sites	*Critical infrastructures*	Factors that make critical infrastructures stop functioning	Existance of lifelines	yes/no
			Degree of interdependance among lifelines	redundancy; emergency devices; autonomous capacity
			Continuity plan for lifelines, individually and in a coordinated fashion	yes/no; considers all potential threats/does not
			Degree of dependance of critical public facilities from lifelines	redundancy; emergency devices; autonomous capacity
	Production sites	Factors that may lead to halting production	Degree of dependance of production sites from lifelines	redundancy; emergency devices; autonomous capacity
			Accessibility to the plant and to markets	redundancy; quality of roads; usability; expected increase in travel time
			Contingency plan for na-tech	yes/no; considers all potential threats/does not
			Business continuity plan	Yes/no
Social system (agents)	*People/individuals*	Factors that may reduce coping capacity during crisis	Access to understandable information	yes/no
			Trust in information provisers	yes/no or percentage
			Preparedness in case of event	yes/no
			Presence of impaired groups (elderly, sick persons, etc.)	yes/no; percentage and location
	Community and Institutions	Factors that may hamper effective crisis management	Existance of contingency plan fro threats at stake	yes/no; date of last production or update
			Training using the contingency plan	yes/no; frequency of training
			Overlapping responsiblities among agencies	Low/medium/high
			Established protocols for information sharing	yes/no
			Established protocols for use of resources to manage the crisis	yes/no/partial

Matrix to assess systemic vulnerability

Fourth Matrix: Resilience: response capability in the long run

System	Component	Aspect	Aspect Parameters	Criteria for assessment
Natural environment	*Natural ecosystems*	Ecosystems capacity to recover from damages	resilience of natural ecosystems to the stress provoked by the natural hazard(s)	refer to studies in ecology; hazard dependant
		Ecosystems capacity to recover from secondary negative effects of emergency mitigation measures	resilience of natural ecosystems to the stress provoked by human intervention in the attempt to prevent losses to settlements and infrastructures	refer to studies in ecology
Built environment	*Exposure and vulnerability of built environment*	Urban fabric/built environment capacity to recover reducing pre-event vulnerability	Temporary transferability of facilities relevant for the settlement/city community life and economy	Yes/no
			Existance of plans for reconstruction in case of severe destruction scenarios	Yes/no
			Existance of skilled workers/firms for repairs and reconstruction (example historic sites)	Yes/no; availability with respect to expected need
			Level of sharing among stakeholders of reconstruction plans	High/low; only formal/substantial
			Level of integration of physical reconstruction with community healing processes	High/low; room for interpreting in the new/restored setting the meaning of the destruction
			Relevance of potentially affected settlements in geographic/economic terms	Central/peripheral
Infrastructure and production sites	*Critical infrastructures*	Availability of tools to recover critical infrastructures rapidly and at low costs	Computerized mapping systems of infrstructures	yes/no
			In site devices for quick survey of damaged parts	yes/no
			Availability of spare materials for fast repairs	yes/no; time needed to bring on site spare materials
			Availability of personnel for repairs	on site/in distant areas; number of available technicians with respect to expected need
			Existance of protocols to proceed with repairs requiring inter-lifelines interventions	yes/no/partial; number of different stakeholders to be coordinated in repair efforts
	Production sites	Availability of tools to recover production sites rapidly and at low costs	Temporary transferability of production in case of need	applicable/not applicable
			Existance of funds for fast repairs	yes/no
			Existance of inspection and guiding personnel for correct repairs	yes/no/forecasted in the recovery plans
			Economic sectors	Diversified or concentrated on few sectors
Social system (agents)	*People/individuals*	People's resilience in the face of the catastrophe induced trauma	Availability of psychological support for adults and children	yes/no/making part of ordinary practices
			Availability of private resources to resettle/repair	yes/no/support by public agencies
			Access to insurance	yes/no/percentage of coverage
	Community	Affected community's resilience to the consequences of a catastrophe	Age structure	Aging population; low fertility rates
			Local condition of aged population	autonomous/not autonomous; relatively healthy/not healthy
			Employment rate	high/medium/low
			Annual population growth rate (over the last five years)	high/medium/low/negative
			Immigration index	high/medium/low/negative
			Social networking	high/medium/low/negative
			Criminality rate	high/medium/low
			Conflict among social/ethnic groups	high/medium/low
	Institutions	Transparency, reliability and trustability of institutions in charge of reconstruction	Degree of trust in institutions	high/medium/low (from sociological surveys when available)
			Transparency in funds allocation	Existance of public information and independent control mechanisms
			Long term vision	Existance of strategic development/land use plans
	Economic stakeholders	Capacity and willingness of stakeholders to reinvest in affected areas	Insurance coverage	Yes/no/percentage
			Dependance of economic actors on loss of environmental goods	Prevalent tourist acitvity; agricoltural activity

Matrix to assess resilience

Risk: drought **First Matrix: Resilience: Mitigation capacity**

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters values and/or categories	Application to case study
Natural environment	*Natural Hazards*	Natural hazards identification and mapping	Hazard maps availability, reporting climatic and hydrological conditions in the area	binary	yes/no	yes (Ministry of Agriculture,Israel Meteorological Service)
				mapping scale	level of detail with respect to scale of decisions regarding land uses	suitable to decisions regarding agricultural and herding practices
			Hazard maps and assesment considers climate change	binary	yes/no	yes
		Available knowledge updating	Hazard maps updating	Frequency of updating	approx. every 5 years	yes
		Hazard monitoring	Yes/no; quality and distribution of monitoring networks	binary; expert judgement upon the quality of networks	yes/no; rainfall and hydrological network available/not available	yes (Ministry of Agriculture,Israel Meteorological Service)
		Integration of weather and precipitation monitoring systems with drought forecasting models	Are there early warning systems	relying on what type of indexes	indexes tailored to the context/not tailored	yes by the Israel Meteorological Service at the beginning of the winter. Yet it has a limited success of cerca 60%
		Structural defence measures	possibility and capacity to use additional water sources	availability/capacity to drill new wells; connect among acqueducts; runoff harvesting; waste water purification	mc of additional water	Yes
			remediation projects for contaminated rivers	capacity to reuse water binary; clear timing of clean up programs	numer of reuse cycles yes/no	yes, three partially, some remediation projects have been carried out; still problems with chemical contamination
			purification of reused water	degree of achieved quality	good/acceptable/insufficient	good
Built environment	*Exposure and vulnerability of built environment*	Inclusion of vulnerability and exposure assessments in land use plans	Risk scenarios availability	binary	yes/no	yes
			Risk scenarios integrating climate change and induced hazards (like fires)	binary	yes/no	yes
			Vulnerability and exposure assessment considered in ordinary plans (example land use)	yes/no; mode of inclusion	binary; only formally/substantially with limitations and specific requirements	yes
	Rules and tools for risk mitigation	Availability, quality and efficacy of mitigation rules	Building codes/rules	building codes embed measures for water saving	yes/no	partially, faucet installation aimed at reducing the amount of water used and controlling the amount of water used during flushing
			Traditional building practice based on hazard knowledge	capacity to re-produce traditional techniques correctly	yes/no; judgement about the capacity to conform to the "code of practice"	Measured are implemented to increase insulation; Yet it is part of the climate and is not necessarily linked to droughts
			Land use plans embedding risk mitigation and vulnerability reduction	binary; sectoral/comprehensive; specific/generic	yes/no; expert judgement	Yes, by the Ministry of Agriculture
			Implementation capacity	pricing policy for wasting water	yes/no	Yes, by the Ministry of Agriculture
			Integration to other measures (insurance)	binary	yes/no	Yes
Infrastructure and production sites	*Critical infrastructures*	Existence of vulnerability assessments for critical facilities; level of consideration of vulnerability in programs regarding critical facilities	Vulnerability assessment of water system	Existance of double piping system for rain/grey water	yes/no	yes for many rural sttlements
				Maintenance programs embedding mitigation	yes/no; frequency of maintenance	yes, maily in chrge by the Ministry of Agriculture
				New projects based on hazard/risk assessment	yes/no	yes
				Treatment plants operationality	fully operational and frequently inspected/missing plants, lack of inspection procedures	yes. Enlargement of existing plans and new plans are constantly taking place
	Production sites	Existence of vulnerability assessments for production sites; consideration of na-techs	Vulnerability assessment of production sites	with respect to water crisis	yes/no	yes
			Production buildings and activities designed to save water	binary	yes/no	partially
			Self storage of emergency water	binary	yes/no	partially
Social system (agents)	*People/individuals*	Evaluation of the capacity of individuals living in prone hazard areas of coping with hazardous events	Risk perception/ awareness	degree	inexistent/average/good	good
			Early warning systems	information addressing all components of communiy(ies)	% of coverage	100%
			Individual preparedness	regarding specific self protective measures; regarding measures included in emergency plans	inexistant/average/good	Overall good for the Jewish farmers and insufficient for the Bedouin farmers
	Community and Institutions	Involvement of a community into decision-making processes related to risk prevention and mitigation, the capacity of Instituions of improving risk awarenees and the level of cooperation among different institutions in charge of risk prevention/ mitigation.	Participation in development and prevention/mitigation strategies	degree	inexistent/average/good	good for Jewish community and average for Bedouins?
			Level of coordination among institutions	degree	low/medium/high	Level of coordination betweenthe Land-use administration responsible for most state-owned land in the Negev; the Jewish National Fund (JNF) responsible for the forested plots, Mekorot: the national water company, responsible for channeling drinking water from the center and northern parts of the country to the Negev and for the purification and channeling of sewage water from the Tel-Aviv metropolitan to the Negev, the Ministry of Agriculture: responsible for research and development and professional instructions, and the Ministry of Finance that introduced the "drought line" demarcating an area as prone to droughts, where farmers are guaranteed the return of expenses in case of droughts is generally good. High levels of solidarity between JFA members, makes JFA a powerful actor vis-à-vis the governmental and financial institutes.
			Councelling for best agricultural and herding techniques	binary	yes/no	yes, the Ministry for Agricolture is responsible and programs do exist
			Education programs & media campaigns	frequency and coverage	very frequent/rare; extended to the entire population at risk/only to limited groups	frequent; addressing also the Bedouin community for shifting from extensive to intensive herding
				thaught at school in ordinary programs	yes/no	yes
			Cooperation among different ethnic communities		high/low/conflict situation	Both conflicts and cooperation between Jewish and Bedouin farmers and between institutional and governmental agents are frequent in the Negev. Theft of Jewish agricultural equipment, crops and water from Mekorot by Bedouins are a common scenario in the Negev, as well as illegal occupation of state-owned land by Bedouins. Evacuation of the invaders from the land that is cultivated, at least, once, is difficult following verdicts by the Israeli Supreme Court. In addition, if their tents are legally destroyed, the state pays compensation to Bedouins. Socio-economic relations between the Bedouin populations and Jewish institutions are characterized by mutual help and cooperation. Land-use authorities allow for sheep grazing on the state-owned lands, and JNF allows, grazing (subject to some restrictions) in its forests. The Ministry of Agriculture actively acquires permissions from the army for entering Bedouin herds into army training zones during the weekends. Bedouin and Jewish guides employed by the Ministry of Agriculture facilitate adequate professional instructions to the sheep owners and farmers. The interaction between the Jewish farmers and the Bedouins include purchasing the right to use waste water of Bedouin towns by the Jeasish farmers. Bedouin workers are widely employed by the Jewish farmers while Bedouin sheep owners purchase from the Jewish farmers the rights to graze on the wheat straw. Jewish farmers also directly sell to the Bedouin sheep owners straw, hay and grains.

Matrix to assess mitigation capacity to drought

Risk: drought **Second Matrix: Physical vulnerability: Vulnerability to stress (drought) and to losses (water scarcity crisis)**

In the case of drought it seems that the distinction between physical and systemic vulnerability as for other hazards does not make sense. First because of the duration of the event, that can last for several months; second because the actual "damage" is the loss of an ecological service (water) which provokes the loss or the scarcity of water in pipes and in rivers. So the two aspects of damage and loss of function seem to coincide

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters values and/or categories	Application to case study
Natural environment	*Natural ecosystems*	Fragility of ecosystems to potential secondary effects of hazard(s)	crops and other agricoltural products by type	relative resistance to lack of precipitation	number of days/minimum mm rain/year	Selected crops have a high resistance to droughts; may yield 10-20% more grains with given precipitation.
				dependence on precipitation	totally rain-fed/irrigation (reused water)	Long-term trend of increasing the water sources and irrigated area in the Negev results in high robustness of the Negev territorial system to droughts. Thirty Years ago 90% of the Negev's fields' crop was wheat; these fields could be used for sheep grazing after the harvest. Currently, half of the cultivated areas are connected to the irrigation systems and are not available for grazing during years when semi-industrial crops or vegetables are grown on these plots.
			sheep and goat	relative resistance to lack of precipitation	number of days/minimum mm rain/year	During severe droughts, when the grain did not reach maturation and harvesting is cancelled. Bedouin herds are allowed to graze on the un-harvested plots during these years, the sheep numbers will grow and their feeding during the next years becomes problematic. A decision to increase the herd due to the high food availability during extreme droughts will cause capital loss during consecutive "normal" droughts when food is less available.
			soil capacity to maintain moisture	type of treatment	tillage/no-tillage; use of organic matters: yes/no	The use of the no-tillage cultivation techniques and special machinery that increase the soil water storage result in an increase in the moisture content of the soil (Bonfil, 1999). Similarly, the addition of organic matter which serves to increase the moisture content of the soil (Cantón et al., 2004) may contribute to the "success" of certain fields. Higher moisture content may also characterize "sun-shaded" aspects such as the northern aspect in the Negev.
				type of rotation	using productions that deplate water content/save water content	The decision to sow a more drought-resistant crop such as barely instead of the more drought-sensitive wheat may determine future vulnerability as well as more general decision on rotation of crops within a field. Despite the general necessity of rotation that aims at reducing the risk of exhausting the fields and the development of diseases, rain-fed wheat may be affected during a next drought year.
		Vulnerability of ecosystems to mitigation measures taken during emergency	crops and other agricoltural products by type	vulnerability to emergency water sources (i.e. desalinized water)	high/medium/low	Emergency water (from runoff or sewage). Only purified sewage water is used. As a rtsult there is no risk of using this water.
			sheep and goat	vulnerability to emergency water sources (i.e. desalinized water) and emergency actions	high/medium/low	On a national level, desalinized water is used. Yet this water is mixed with ions before reaching the fields and thus risk that stem from lack of necessary cations and anions is avoided. As for sheep and goat, during severe droughts actually the food for herd increses leading to a more vulnerable situation
Built environment	*Exposure and vulnerability of built environment*	Factors that make exposed systems vulnerable to drought	Vulnerability assessment of buildings	type and maintenance of pipes; needed pressure to have water at taps	designed for dry climate/ordinary pipes; large pressure needed/low pressure	The existence of a double system (for domestic use and for agriculture) reduces the vulnerability of the system
				emergency water storage	yes/no	Local reservoirs of runoff and sewage water. Yet, one has to note that these systems are not designed for emergency periods but one there, they may be used during such periods
				minimal water need/day/type of building use	l/day/type of use: residential, hospital, school, other public facilities	DO YOU MEAN(?): shortage of water sources and water quata, inproper cultivation techniques.
Infrastructure and production sites	*Critical infrastructures*	Factors that make critical infrastructures vulenrable (mainly lifelines)	Vulnerability assessment of water system	average lifelitime of wells	months	Inadequate planning of water usage; technical difficulties in operating the facilities used for waste water purification
				minimal threshold of water needed in tanks and reservoirs	cm	Since all water of the entire country is centrally controlled, over pumping and excess of water usage will ffect the entire country and may not be confined to one particular region
			Availability/capacity to use emergency alternative sources	binary; estimation of mc that may be addeded to the system	yes/no; mc	see above
	Production sites	Factors that make production sites vulnerable (including na-tech potential)	Vulnerability assessment of production sites	degree of dependence of activity on water	high/medium/low	low; Since irrigated crops are sown prior to any knowledge regarding drought and are hardly affected by drought, only production that is based on rain-fed wheat and summer crops (which are mainly planted following a wet year) will be affected
				emergency water storage	yes/no; days of autonomy	see above
Social system (agents)	*People/individuals*	Factors that create discomfort for the population and as an ultimate resource the need to evacuate	Access to water sources per type and quality	degree	to all sources/partial/severely restricted	Both sources, dribking and purified water are used by both communities. Yet, as the usage of purified water necessitate high solidarity between the farmers and a strong "lobby" that will act to acquire bank funding, Jewish farmers can much easily invest in the costly facilities that purify wate and therefore are the main consumeres of purified water
			Population living in the driest areas	Number	l/day availble in drought conditions	No evacuation of people due to drought takes place. Yet, at a long run, immigration, especially of the Bedouin population from the rural settlements to the cities may take place due to reduced income
			Preparedness	degree	high/medium/low	high for the Jewish sector, medoium for the Bedouin sector
			Access to information about water saving strategies	degree of coverage	> 70%population/< 50% population	high for the Jewish sector, medoium for the Bedouin sector
			Contingency plan	binary	yes/no; shared among stakeholders/known by few	high
	Community and Institutions		Access to information about compensation and alternative sources of revenue	degree of coverage	> 70%population/< 50% population	Despite the compensation, the fields within the "drought line" do not yield income and the compensation cannot prevent the severe economical influence of drought on the farmers. Compensation relates to the expenses but not to the loss of revenue

note: there are some measures taken to reduce vulnerability to severe droughts that create vulnerability to more frequent droughts. (the vice versa can also be the case. Interesting)

Matrix to assess physical vulnerability to drought

Risk: drought; case study: the Northern Negev area **Fourth Matrix: Resilience: response capability in the long run**

	System	Aspect	Parameters	Criteria for assessment	Descriptors	Application to case study
Natural environment	*Natural ecosystems*	Ecosystems capacity to recover from secondary negative effects of emergency mitigation measures	Process of crops and other agricoltural productions recovery	Needed time and water	Months; minimal mm precipitation	Hypothetically, drought may cause large abandonment of the Jewish settlements and immigration of the Bedouin population from the rural settlements to towns. However, such an extreme scenario is unrealistic. Droughts serve as a trigger for irrigating rain-fed plots and enforce Jewish farmers to increase the investments in water supply. By forming a lobby in favor of government investment in the development and transfer of water from the wetter parts of the country, and in additional local water sources, Jewish farmers substantially increased the system resilience. An increase of the urban population instead causes steady increase in the amount of the sewage water that serves in turn for irrigation (following purification)
		Capacity to introduce all mitigation measures envisaged in the first matrix during the window of opportunity opened during recovery	See first matrix as far as monitoring and structural defences are considred	binary	yes/no	
Built environment	*Exposure and vulnerability of built environment*	Urban fabric/built environment capacity to recover reducing pre-event vulnerability	Existance of plans/adjustments for recovery after severe drought periods	binary	yes/no	Droughts trigger the search for technical means to alleviate the effect of the drought, increases investments in water supply, and establishes economic mechanisms of crediting investments during the crises. Adaptation of new varieties of sheep, new insemination techniques, development of intensive sheep raising contribute to the resilience of the Bedouin sector to droughts. Investments and development of new water sources, extending the pipeline network, introducing new wheat varieties, increasing the moisture stored at the soil with the new agricultural techniques, all these consistently increases the coping capacity of the Jewish sector.
			Do adjustments reduce vulnerability to future droughts	binary	yes/no * *careful assessment needed regarding adjustments for frequent/severe droughts that may be counterproductive in case of frequent/severe droughts*	The use of purified sewage water for irrigation. Extension of the irrigated areas is the most important part of the northern Negev development during the last 20 years. The revenues from the irrigated crops are several times higher than that from the rain-fed crops, thus substantially increasing farmers' capacity to cope with the unfavorable weather conditions.
			Relevance of potentially affected settlements in geographic/economic terms	Type of settlement	rural low density areas/ urban areas/cities	In the project cities like Beer Sheva were excluded and attention was concentrated on the two types of settlements pertaining to the two communities. The Jewish farmers live in Moshav and Kibbutz structures, while the Bedouins are organised in families. Attempts to structure Bedouins' communities in settlements served with lifelines and other services succeeded only in part. While illegal occupation of State owned land is still very frequent and in those cases access to facilities is substantially less secure.
Infrastructure and production sites	*Critical infrastructures*	Availability of tools to recover critical infrastructures rapidly and at low costs	Computerized mapping systems of infrstructures	binary	yes/no	yes
			Possibility to improve the water system	binary	yes/no	yes
			Availability of extra water sources	binary and number	yes/no; mc estimated	yes
			Availability of technologies to reuse water	binary; type of technology	yes/no	yes reference to the table provided in the text
			Availability of technologies and practices to save water	biinary; type of technology	yes/no	yes, the use of the drip irrigation (saves half the amount of water in comparison to the traditional systems); use of domestic means that save domestic water use
	Production sites (other than agricolture)	Availability of tools to recover production sites rapidly and at low costs	Temporary transferability of production in case of need within region/country	binary	yes/no	no
			Existance of funds for repaying costs and new investments	binary; amount	yes/no	The ministry of finance provides financial umbrella to the insurance of the farmers against the drought's hazard and, also, to immediate financial compensation provided to the farmers following droughts. Despite the compensation, the fields within the "drought line" do not yield income and the compensation cannot prevent the severe economical influence of drought on the farmers.
Social system (agents)	*People/individuals*	People's resilience in the face of the catastrophe induced trauma	Availability of private resources to resettle/recover	binary	yes/no; support by public agencies/relying only on private funds	Yes, public funding. Strong lobbying by the Jewish farmers association.
	Community	Affected community's resilience to the consequences of a drought	Presence of elderly and particularly vulnerable people(sick, impaired)	percentage		
			Employment rate	degree	high/medium/low	high in the Jewish sector; much lower in the Bedouin sector
			Annual population growth rate (over the last five years)	degree	high/medium/low/negative	medium in the Jewish sector; extremely high in the Bedouin sector (the highest in the world)
			Immigration index	degree	high/medium/low/negative	Low
			Social networking	degree	high/medium/low	A positive social effect of the drought is the intensification of the intra-relationships and solidarity between the community members, especially in the aJewish sector.
			Conflict and cooperation among social/ethnic groups	degree	high/medium/low	Droughts affect interaction between the Jewish farmers and the Bedouin sheep owners. Jewish farmers may allow grazing while the Bedouin sheep owners may decide whether to purchase the right to graze on agricultural fields or rather to purchase hay to feed the sheep at the barn or paddock in their own property. The decision of the Jewish farmers to restrict grazing on agricultural fields may, on one hand, reduce the number of herds in the Northern Negev; on the other hand this may enforce new husbandry techniques. A decision of the sheep owners not purchase the right to graze on the fields may enforce Jewish farmers to use the straw as mulch.
	Institutions	Are institutions in charge of reconstruction transparent, reliable and trustable?	Degree of trust in institutions	degree	high/medium/low	high for the Jewsish farmers; medium for the Bedouins
			Transparency in funds allocation	Existance of public information and independent control mechanisms	yes/no	yes
			Long term vision	Existance of strategic development/land use plans	yes/no	yes
				Level of sharing among stakeholders of recovery plans and adjustments	High/low; only formal/substantial	Currently, half of the cultivated areas are connected to the irrigation systems and are not available for grazing during years when semi-industrial crops or vegetables are grown on these plots. The amount of fields available for grazing is thus constantly decreasing. Consequently, the pressure, on the Bedouin farmers, to switch from extensive to intensive sheep-raising is increasing. This is accompanied by internal changes of the Bedouin society, higher education demand and refusal of the young generation to serve as shepherds. Yet, the reduction in the Bedouin sheep-feed areas is accompanied by higher yield of wheat from the plots irrigated a year before. Indeed, following crop rotation, wheat is often grown on plots that were used for irrigated semi-industrial crops or vegetables a year before. As a result, the amount of straw at these plots is substantially higher than on plots that were not irrigated. In this way the irrigated plots may compensate, at least partially, for the reduction in the amount of the fields available for Bedouin grazing.
				Compensation mechanisms integrate risk mitigation measures	yes/no	Currently, the investments of the Jewish farmers into new water sources are continuously increasing. The tendency of the Bedouin sheep owners to switch to intensive raising is also noted. We do not have yet a definite answer whether a reduction in the grazing area could enforce the switch from extensive to intensive sheep raising. Yet, our preliminary results point to such a possibility.
	Economic stakeholders	Willingness and capacity of economic stakeholders to reinvest in affected areas	Insurance coverage	Coverage	%	all Jewish sttlements; only a small part of the Bedouin farmers
			Dependance of economic actors on loss of environmental goods	Prevalent tourist acitvity; agricultural activity	percentage on GNP (of the region/country)	Agricultural yield is responsible for above average GNP due to the Negev advantage in early maturation of winter crops and the high proces received for theses goods abroad

Risk: flood; Case study: Severn, flood 2007 **First Matrix: Mitigation capacity**

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters values and/or categories	Application to case study
Natural environment	*Natural Hazards*	Natural hazards identification and mapping	Hazard maps availability	binary	1, yes/no	
			Hazard maps scale	scale and level of detail with respect to planning decisions	county level, neighborhood level, single building level	
			Considers domino effects	Considers potential na-tech	yes/no, only partially	
		Hazard monitoring	Hazard maps considers climate change	binary	yes/no	
			Dos a monitoring network exist?	binary	yes/no	
			quality and distribution of monitoring networks	expert judgement upon the quality of networks	high/low	
		Integration of weather and flood detection and monitoring systems with hydraulic and hydrologica/hydrographic flood forecasting models	Does an instrumented flood detection and monitoring system exist (i.e. a hydrometric network) ? How much of the geographical area does it cover ?	Binary, % area coverage	Yes/No, <30%, 30-60%, >60%	Capacity to take preventative action for pluvial flooding is limited because of the time taken to react (especially at night-time) and short warning lead times. Capacity to respond to fluvial flood warnings is relatively good.
			are there early warning systems?	binary; quality	yes/no; expert judgement	
		Flood forecasting	Flood forecasting capability	Resolution capability	Low, medium, high	
		Flood warning	Is severe weather warning integrated with flood warning to lengthen the overall warning lead time ?	Binary	Yes/No	
			Flood warning timeliness	Warning lead time	Very short (<30 mins), short (30-180 mins), medium (181 mins - 12 hrs), long (>12 hrs)	
		structural defence measures	Do they exist, what is the defence standard	binary; Return Period for which protection is set	Yes/No, 50, 80, 100, >100 yrs	The Lower Severn sub-region has few raised structural flood defences (there are some low earth embankments and pumped drainage systems) to protect against fluvial flooding, although there are flood embankments around the edge of the estuary which provide a high level of protection against tidal flooding. Structural flood protection for fluvial flooding is largely impracticable because of floodwater displacement and transfer implications.
			Do protection standards take climate change into account ?	Binary	Yes/No	
			Condition of defences	Is condition assessed regularly (a) point installations: binary (b) linear defences: binary ?	(a) Yes/No, %age in excellent, good, poor condition (b) Yes/No, %age in excellent, good, poor condition	Point installations include flood gates, pumping stations etc
			Maintenance	(a) Does a systematic plan exist for maintenance: binary (b) is maintenance budget guaranteed: binary ?	Yes/No, Yes/No	
			Is space available to construct, reconstruct or realign defences ?	Binary	Yes/No	
			Flood retention areas (a) Do they exist ? (b) Does land use planning allow for potential retention areas for the future to be protected from development ?	(a) Binary (b) Binary	Yes/No, Yes/No	
			Are natural flood buffer zones maintained and/or reinstated when lost ?	Binary	Yes/No	These include beaches, marshes, mudflats and natural habitats
Built environment	*Exposure and vulnerability of built environment*	Inclusion of vulnerability and exposure assessments in land use plans	Vulnerability assessment of exposed built stock	binary ; updating frequency	yes/no; every 5 ys/only after floods	
			Risk maps and scenarios, including enchained events	binary; RP considered	yes/no; only frequent events/also rare events	
			Vulnerability and exposure assessment considered in ordinary plans (example land use)	binary; mode of inclusion	yes/no; only formally/substantially with limitations and specific requirements	As the floodplain settlements of Gloucester and Tewkesbury have grown in response to economic growth, so they have further extended in some cases into the floodplain because of the absence of alternative development land in attractive locations. Even so since 1947 the planning and development control system has restrained development in flood zones.
	Rules and tools for risk mitigation	Availability, quality and efficacy of mitigation rules	Building codes/rules	binary; updated	yes/no; judgement of effectiveness upon "age" of rules with resepct to state of the art	Capacity to control building standards came with the introduction of building codes which have a long history in the UK. These codes, now well enforced, will have avoided gross instances of a lack of basic structural integrity and resilience to flooding. Today's building codes do not include detailed flood resilience standards but there are plans to correct this.
			Rules for retrofitting	Binary	Yes/No	
			Flood resilience built into new projects and programmes	Binary	Yes/No	
			Traditional building practice based on hazard knowledge	binary; capacity to re-produce traditional techniques correctly	yes/no; judgement about the capacity to conform to the "code of practice"	
			Maintenance of building stock	binary; economic incentives	yes/no; exist/not foreseen	
			Land use plans embedding risk mitigation and vulnerability reduction	binary; expert judgement	binary; sectoral/comprehensive; specific/generic	In response to the spreading of urbanisation into the countryside in England and Wales, in 1947 the nation introduced a universal land use control system (the Town and Country Planning System). This required most development proposals to acquire planning consent before development could take place.
			Implementation capacity	binary; frequency of inspections; trained personnel for inspections	yes/no; availability of budget for personnel to advice and inspect	
			Integration to other measures (insurance)	binary	yes/no (what conditions)	Flood insurance premiums have a limited fit to level of flood risk. Flood insurance companies do not yet reduce premiums for those who have installed resilience measures.
			Projects of access ways to and within hazardous areas	binary	yes/no	It has proved very difficult to develop a transportation system for the Lower Severn which is not flood prone. As a consequence many roads and some rail lines are flooded from time to time. Adoption of Sustainable Urban Drainage Systems (SUDS) has now become mandatory and this will help limit surface water flooding of road systems.
Infrastructure and production sites	*Critical infrastructures*	Existence of vulnerability assessments for critical facilities; level of consideration of vulnerability in programs regarding critical facilities	Vulnerability assessment of critical infrastructure	binary ; updating frequency	yes/no; anytime new project/repair needed/only after floods	Capacity to locate utility installations in flood-free locations has been limited. There has been a long-standing tendency to locate utility installations on areas of low-lying ground, which were apparently 'waste' land and not used for other purpose - developing a legacy of flood prone infrastructure
			Maintenance programs embedding mitigation	binary	yes/no	
			New projects based on hazard/risk assessment	binary	yes/no	Detailed studies have recently been done to develop and publicise flood resilience and flood resistance measures for critical and other infrastructure (McBain et al., 2010). New infrastructure will need to proceed through flood risk assessment procedures in future and processes now exist for this.
			Level of coordination among stakeholders	expert judgement	low/medium/high	
	Production sites	Existence of vulnerability assessments for production sites; consideration of na-techs	Vulnerability assessment of production sites	binary ; updating frequency	yes/no; anytime new project/repair needed/only after floods	
			Retrofitting measures for existing production sites	binary	yes/no	
			New projects based on risk assessment	binary	yes/no	
			Na-tech explicitly accounted for in hazardous installations emergency plans	binary; expert judgement on quality	yes/no; in generic terms/through detailed assessment	
			Commercial flood insurance	Binary; extent of coverage	Yes/No, low/medium/high	
Social system (agents)	*People/individuals*	Evaluation of the capacity of individuals living in prone hazard areas of coping with hazardous events	Risk perception/ awareness	questionnaires, surveys, judgement after event	Negligible or low/average/good	In Gloucester 34.9% of residents have lived in their house for less than 5 years (the equivalent statistic for Tewkesbury is 35.2%) (Gloucestershire County Council 2009). Although these statistics do not relate specifically to the portion of these settlements which are flood prone, they are an indicator of the degree to which the local population has the capacity to manage flood risk and is likely to be inexperienced in flood risk and its successful management. Such residential mobility is a feature of a relatively prosperous urban society of which the Lower Severn area is part.
			Access to flood information including flood maps, explanation of warning codes, appropriate actions	Binary; map quality	Yes/No; map quality good/fair/poor	
			Flood insurance	Binary; coverage	Yes/No, low/medium/high	
			Training and experience of population/communities	Qualitative judgement	Low/medium/high	
			Individual preparedness	regarding specific self protective measures; regarding measures included in emergency plans	Negligible or low/average/good	Everyone with access to the internet (internet access is around 80%) is able to access indicative flood maps provided by the Environment Agency. By clicking on the precise location of a property, a property owner can read an assessment of the risk of flooding to that property. This data is publicised by the Environment Agency at local farmers' markets and special flood fairs, as well as in other ways.
	Community and Institutions	Involvement of a community into decision-making processes related to risk prevention and mitigation, the capacity of Institutions of improving risk awarenees and the level of cooperation among different institutions in charge of risk prevention/ mitigation.	Participation in development and prevention/mitigation strategies	binary and level of involvement	yes/no; only formal/encouraged participation	
			Education programs & media campaigns	binary and frequency	yes/no; regularly carried out/only occasionally	flood risk awareness and how best to prepare for flooding is not as well comprehended as it needs to be in these communities despite recent flood events. Through mechanisms such as the above roadshows and the Flood Information Network, local capacity has been developed to introduce local people to flood products which can increase the resilience of homes and other structures to flooding.
			Awareness programs as part of ordinary teaching programs	binary	yes/no	
			Capacity to invest in mitigation	Qualitative judgement	Low/medium/high	
			Coordination and cooperation among institutions in charge of risk prevention/ mitigation	judgement	good/partial/low	
	Economic stakeholders	Level of preparedness of key economic stakeholders	Capacity to invest in mitigation	Qualitative judgement	Low/medium/high	
			Business continuity plans	binary	yes/no	

Matrix to assess mitigation capacity to flood

Risk: flood; Case study: Severn, flood 2007 **Second Matrix: Physical vulnerability: Vulnerability to stress (hazard)**

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters values and/or categories	Application to case study
Natural environment	*Natural ecosystems*	Fragility of natural ecosystems to hazard(s)	Are different crops/agricolture productions vulnerable?	height of water; quality of flooding water; duration of flood	mt; concentration of contaminants; days	Average agricultural flood damage cost were about £1,150 per flooded hectare when weighted by land use
		Possibility of enchained effects due to the interaction of natural systems with the triggering hazard	Is there a possibility of solid trasport mechanisms	binary/expected volume of material	yes/no; mc	
		Vulnerability of ecosystems to mitigation measures taken during emergency	River diversions taken to reduce the hazard severity may subtract water from areas that need it?	binary	yes/no	
Built environment	*Exposure and vulnerability of built environment*	Factors that make buildings, the urban fabric and public facilities vulnerable to the stress	Buildings structural vulnerability	timber/mud/stone/bricks/reinforced concrete	timber/mud/stone/bricks/reinforced concrete	Different depth-damage curves for each house type to be allocated to properties in flood risk zones.
				Number of floors	1/2/ >2	Number of high rise buildings is very low in terms of proportion of total.
				Level of the first floor with respect to expected flood	lower level/same/higher level	
				Existance of basement	yes/no	
			Properties within flood risk zone	Number and type of properties	Numbers from survey or secondary data	
			Position with respect to hazardous zones	Distance and position with respect to expected flood height	in the rapid inundation zones/at higher levels	It was the strategic position of Gloucester at a bridging point of the River Severn that led to the creation of the original settlement which then gradually spread out the wide estuarial floodplains. The town of Tewkesbury has similar origins being located strategically at the confluence of the Rivers Severn and Avon. This town has a population today of 10,000 and its growth and development has been very significantly constrained by the flood risk zones which surround it.
			Content of buildings	valuable objects in first floors	yes/no; type of valuable objects	
			Resistance and resilience of structural mitigation measures	Vulnerability to stress, maintenance regimes etc.	Qualitative judgement - low/medium/high	
			Non-structural mitigation measures e.g. early warning systems	Binary	Yes/no	
			Proximity to hazardous land uses	Type of land use and distance	Estimate of distance e.g. <500m, 500m - 1,000m etc.	
			Vulnerability assessment of public facilities	As for buildings but distinguishing by function		
			Vulnerability of the urban fabric	Consiering entire neighborhoods	Population density: high, medium, low	Average house damage insurance claims were £30,000 - £40,000
Infrastructure and production sites	*Critical infrastructures*	Factors that make critical infrastructures vulenrable (mainly lifelines)	Water treatment plants; electical power plants; other lifelines plants	Distance and position with respect to expected flood	in the most critical zone/in a rarely flooding zone	The principal vulnerable installation is the Mythe Water Treatment works which was flooded in 2007. Physical damage to these works are estimated at £29.6 millions, without considering costs o distribution of water bottles. The Castlemeads Electricity substation was also flooded.11 Sewage Treatment Works and 40 Sewage Pumping Stations were flooded and all had to have equipment replaced afterwards.
				Ordinary maintenance	yes/no	
				Existance of emergency provisions to protect from floods	yes/no	The much larger Waltham Electricty Station supplying millions of consumers cam within 4 cms of flooding but was saved from flooding by emergency resilience measures
				Na-techs are considered in emergency procedures	yes/no	
	Production sites	Factors that make production sites vulnerable (including na-tech potential)	Vulnerability assessment of production sites	Distance and position with respect to expected flood	in the most critical zone/in a rarely flooding zone	500 businesses directly affected by flooding
				Existance of emergency provisions to protect structures from floods	yes/no	
				Na-techs are considered in emergency procedures	yes/no	
				Existance of provisions to protect stocked material and machinery	yes/no	
			Vulnerability due to dependence on lifelines	Qualitative judgement	Low/medium/high	
			Proximity to dangerous land uses	Type of land use and distance	Estimate of distance e.g. <500m, 500m - 1,000m etc.	
Social system (agents)	*People/individuals*	Factors that may lead to injuries and fatalities	Location with respect to vulnerable buidlings, roads, industrial sites	People that may be trapped in flooding buildings of different types (residential, public, etc.)	number of people; location in maps	The potential of floods to kill people in the Lower Severn area is normally low because flooding is usually shallow. Two people died in the summer 2007 floods in Gloucestershire as an indirect effect of flooding.
			Preparedness	People know what to do in case of flood warning	yes/no; extent of compliance with norms in emergency plans	
			Age; mobility impairment, other impairment	difficulties to comply with evacuation orders; difficulties in escaping	number of people; location in maps	
			Depth of flood dangerous for individuals	Curves depth/individuals stability		
			Number of storeys in buildings where people live	Single-storey buildings e.g bungalows	%age of housing stock which is single storey	
			Temporary houses with low robustness hosting people	Caravans/mobile homes/chalets	Number of people living in these	
			Lack of high level exit routes and safe havens for people to escape		Yes/no	
	Community and Instituions	Factors that may lead to large number of victims	Population density in vunerable areas	Population density in different hazard areas	Maps	
			Numbers of tourists/visitors in vulnerable areas	difficulties to comply with evacuation orders and knowing what to do	Number of tourists/visitors	

Matrix to assess physical vulnerability to flood

Risk: flood; Case study: Severn, flood 2007 **Third Matrix: Systemic vulnerability: Vulnerability to losses**

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters values and/or categories	Application to case study
Natural environ	*Natural ecosystems*	Fragility of ecosystems to potential secondary effects of hazard(s)	Are crops and other agricoltural productions vulnerable to contaminated water	by type of production and concentration/type of contaminant	detailed analysis of potential contaminants sources in the area needed	
			Areas that may be vulnerable to secondary contamination	along the river, considering dispersion mode of contaminants	Contaminants, rock, stones, boulders, mud; transportation pocesses	
Built environment	*Exposure and vulnerability of built environment*	Factors that make buildings, the urban fabric and public facilities vulnerable to losses	Existance of public facilities: hospitals, fire brigades, emergency control rooms	yes/no; functional capacity of such facilities	assessment of functional potential of facilities	
			Facilities which posses underground elements such as access routes, basements, tunnels	Binary, extent	Yes/No; lengths of routeways, proportion with underground facilities	
			Lack of safe (e.g. high level) exit routes from underground facilities or from flooded buildings	Binary, extent	Yes/No; lengths of routeways, proportion with underground facilities	
			Range of service of public facilities	Importance of facilities in the potentially stricken areas	Local facilities/regional/national relevance	
			Accessibility to vulnerable areas	redundancy; quality of roads; usability; expected travel time		10,000 motorists stranded on motorway system. 500 rail passengers stranded. Tens and thousands more with disrupted travel for several weeks. Aaccess to Tewkesbury was maintained by a single rail line during the summer 2007 floods.
			Accessibility to public facilities	redundancy; quality of roads; usability; expected travel time		
Infrastructure and production sites	*Critical infrastructures*	Factors that make critical infrastructures stop functioning	Existance of lifelines	binary	yes/no	
			Degree of interdependance among lifelines	level of redundancy; binary	high redundancy; emergency devices exist/do not; autonomous capacity exist/does not	
			Continuity plan for lifelines, individually and in a coordinated fashion	binary	yes/no; considers all potential threats/does not	
			Degree of dependance of critical public facilities from lifelines	binary	autonomous plants exist/do not; alternative resources available/not available	
			People and areas depending on lifelines in potentially affected zones	number/area dimension	number of customers who may be affected; geographic area	Number affected through loss of potable water supplies: 135,000 homes or 350,000 people for 17 days: i.e. 340,000 people outside the flood risk zone. Adaptation comprised providing large number of bottled water supplies but not without availability problems in some areas.
			Duration of outages	hours/days	few hours/> 24	Number affected by loss of electricity power supplies: 48,000 homes or 111,840 people for up to 2 days: i.e. c100,000 affected outside of flood risk zone.
	Production sites	Factors that may lead to halting production	Degree of dependance of production sites from lifelines	binary	autonomous plants exist/do not; alternative resources available/not available	500 businesses directly affected by flooding, additional 7,500 businesses outside of flood risk zone affected by loss of water supplies for 17 days
			Transferability to other production site(s)	Binary or degree	Yes/no or none/partial/most	
			Accessibility to the plant and to markets	redundancy; quality of roads; usability; expected increase in travel time	only 1 road/more alternatives; local/regional/state roads; <2hours/>4 hours	Relatively high level of redundancy in road system (except many roads normally run near capacity at rush hour) and for lateral routes across Severn valley which will have involved lengthy diversion routes (e.g. 100 kilometres). Traffic diversions enabled transferability of travel in many cases but increase in costs as a consequence.
			Contingency plan for na-tech	binary	yes/no; considers all potential threats/does not	
			Business continuity plan	binary	yes/no	Business continuity planning has become relatively well developed in the UK in the past decade and so we would expect many flood risk firms to have considered how they would ensure business continuity during a flood disaster. How many would probably not have considered prolonged loss of potable water supplies caused by flooding in the summer 2007 floods.
Social system (agents)	*People/individuals*	Factors that may reduce coping capacity during crisis	Access to understandable information	binary and redundancy	yes/no; radio and TV/special telephone number/internet	Everyone is able to obtain geographically specific flood warning information and flood advice (including on flood resilience measures) by telephoning the Environment Agency's FLOODline. Radio information is also available.
			Trust in information provisers	binary or degree	yes/no; good/average/ low	
			Preparedness in case of event	degree	good/partial/low	People received severe weather and flood warnings but most did not expect utilities to suffer outages and so they were not prepared for this in most cases.
			Existance of individual/community plan for evacuation	binary	yes/no	
			Availability of temporary shelters	degree	good/partial/low	825 homes (1950 people) were evacuated to rest centres provided by the local authorities
			Availability of temporary location for patients/ill people	binary	yes/no	
	Community and Institutions	Factors that may hamper effective crisis management	Existance of contingency plan fro threats at stake	binary; date of last production or update	yes/no; recent/old	
			Training using the contingency plan	binary; frequency of training	yes/no; every 2 years/>2 years	
			Overlapping responsiblities among agencies	degree	Low/medium/high	
			Established protocols for information sharing	binary	yes/no	
			Established protocols for use of resources to manage the crisis	degree	yes/partially/no	
	Economic stakeholders	Economic stakeholders preparedness to face crises	Capacity to run economy and respond to crises	degree	yes/partially/no	
			Capacity to invest in recovery and take preventive actions	Binary or degree	Yes/no or none/partial/high	

Matrix to assess systemic vulnerability to flood

Risk: flood; Case study: Severn, flood 2007 **Fourth Matrix: Resilience: response capability in the long run**

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters values and/or categories	Application to case study
Natural environment	*Natural ecosystems*	Ecosystems capacity to recover from damages	Resilience of crops and other agricoltural production to floods	Depending on depth and duration of flood water contamination and type of crops/production	Resilient/partially resilient/non-resilient	
		Ecosystems capacity to recover from secondary negative effects of emergency mitigation measures	Water quality in river	Binary	Remediation required/not required	
		Structural defences	Retention areas	binary/legal provisions	can be accomodated/cannot; legal impediments to taking/subtracting to development	Central government and the Environment Agency are following a flood risk management strategy called 'Making Space for Water' which is based on the concept of addressing flood hazards by employing a creative mix of structural and non-structural flood measures (Defra 2005).
			Levees	binary/funding	can be built/cannot be built; funding mechanisms in the reconstruction program	
			Demountable flood defences	Applicable: binary, available: binary	Yes/No, Yes/No	
Built environment	*Exposure and vulnerability of built environment*	Urban fabric/built environment capacity to recover reducing pre-event vulnerability	New development and refurbishing programs include risk prevention as a routine/everyday practice	degree or extent	yes/partially/no	Detailed formal flood risk assessment procedures for siting of new buildings exist in the study area and the whole of England and Wales (DCLG 2010). These must be undertaken at a range of resolutions from strategic to site scales. Even so, 7% of new dwellings constructed in 2008 were located in high flood risk zones in South-West England which is the planning region within which Gloucestershire is located
			Detailed analysis of damage	degree and scale	yes/partially/no; at individual building/neighborhood/municipal scale	Detailed damage analysis at individual building scale has been carried out
			Building codes address flood risk for new construction and retrofitting	degree; compliance	yes/partially/no	However, flood resilience measures are not yet included in these building codes but will be in the next few years. There are now about 400 'flood products' on the market which property owners can purchase and install. So far relatively few properties have been retrofitted with flood resilience measures in the case study area although a few have.
			Availability of partial relocation programs during reconstruction for the most critical situations	binary	yes/no	Not known
			Ability to incorporate recovery/resilience measures in future urban redevelopment plans	Binary, degree	Yes/no, none/partial/high	
			Level of sharing among stakeholders of reconstruction plans	binary	High/low; only formal/substantial	The Environment Agency's is working on a number of key flood alleviation schemes, which amount to a further £5.2 million of activity. A wide range of jointly-funded project drainage and culvert works, de-silting, the raising of banks and flood reinforcement are being carried out to reduce the county's vulnerability to flooding. The County Council is working closely with the district and borough councils on over 50 major drainage improvement projects which will cost a total of £1.9 million
			Existence of skilled workers for reconstruction activites	degree	yes also with specific skills/yes/no	important to understand whether or not there are skilled workers for example in the sector of historic buildings restoration
			Relevance of potentially affected settlements in geographic/economic terms	degree of relevance	Central/peripheral	
Infrastructure and production sites	*Critical infrastructures*	Availability of tools to recover critical infrastructures rapidly and at low costs	Computerized mapping systems of infrstructures	binary	yes/no	
			In site devices for quick survey of damaged parts	binary	yes/no	
			Availability of spare materials for fast repairs	binary; time needed to bring on site spare materials	yes/no; < a day/>1 day	
			Availability of personnel for repairs	binary; number of available technicians with respect to expected need	on site/in distant areas; proportional to needs/few workers	
			Existance of protocols to proceed with repairs requiring inter-lifelines interventions	degree; number of different stakeholders to be coordinated in repair efforts	yes/partially/no; protocols among all companies or coordinated by authorities/limited agreements	
	Production sites	Availability of tools to recover production sites rapidly and at low costs	Temporary transferability of production in case of need	binary	applicable/not applicable	
			Existance of funds for fast repairs	binary	yes/no	
			Existance of inspection and guiding personnel for correct repairs	binary	yes/no/forecasted in the recovery plans	
			Economic sectors	Diversified or concentrated on few sectors	Few/many different economic sectors in the area	Gloucestershire has a diversified urban economy according to the Provisional Economic Strategy 2008-2015 (Gloucestershire First 2007) but the rural economy remains too dependent upon the agricultural sector.
Social system (agents)	*People/individuals*	People's resilience in the face of the catastrophe induced trauma	Availability of psychological support for adults and children	binary	yes/no;making part of ordinary practices/exceptional	
			Availability of psychological and physical support for those with special needs	Binary; degree of support	Yes/no, good/fair/poor	
			Level of skills and capacity to learn and adapt	Qualitative jjudgement	Low/medium/high	
			Availability of private resources to resettle/repair	binary and level of support by public organisations	yes/no; higly supported/lack of advisory personnel	Income polarisation is a persistent problem that has proved resistant to reduction. Gloucestershire has small pockets of deprivation (financial as well as other forms of deprivation). A range of welfare and other policies exist which seek to target this problem but success has not yet been achieved.
			Access to public relief funds, and funds and advice from public organisations	Binary, level of support	Yes/no; high/medium/low support	
			Access to insurance	binary; percentage of coverage	yes/no; %without insurance	In Gloucestershire, 1,300 houses suffered significant contents damage, and of these 270 had not purchased contents insurance (i.e. 20.8%)
	Community	Affected community's resilience to the consequences of a catastrophe	Age structure	age groups and fertility	Aging population; low fertility rates/young	
			Local condition of aged population	percentage of autonomous and healthy population	autonomous/not autonomous; relatively healthy/not healthy	
			Employment rate	degree	high/medium/low	
			Annual population growth rate (over the last five years)	trend	high/medium/low/negative	
			Immigration index	new immigrants/emigrants	high/medium/low/negative	
			Social networking	qualitatie judgement	high/medium/low/negative	
			Criminality rate	degree	high/medium/low	
			Conflict among social/ethnic groups	degree	high/medium/low	
	Institutions	Transparency, reliability and trustability of institutions in charge of reconstruction	Degree of trust in institutions	degree	high/medium/low (from sociological surveys when available)	
			Transparency in funds allocation	binary	Existance (yes/no) of public information and independent control mechanisms	Grants are now available to the public for installing flood resilience measures.
			Ability to learn from past events	degree	high/medium/low	
			Long term vision	Existance of strategic development/land use plans	yes/no/only formal	
			Capacity to avoid income polarization	degree	existence of specific plans/generic statements	
			Corruption	degree	abnormal/average/minimal	
	Economic stakeholders	Capacity and willingness of stakeholders to reinvest in affected areas	Insurance coverage for direct damage and loss of workdays	binary; percentage of coverage	yes/no; %without insurance	
			Dependance of economic actors on loss of environmental goods	Prevalent tourist acitvity; agricoltural activity	percentage	
			Access to knowledge about flood resistant structures	degree	high/medium/low	
			Access and information about funds for reconstruction	degree	high/medium/low	
			Degree of diversification and capacity to spread risks	degree	high/medium/low	

Matrix to assess resilience to flood

Risk: Landslides **First Matrix: Resilience: Mitigation capacity**

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters values and/or categories	Comments
Natural environment	*Natural Hazards*	Natural hazards identification and mapping	Landsilides hazard maps availability	binary; scale of detail	yes/no; local/regional	
		Available knowledge updating	Hazard maps updating	Frequency of updating	on the basis of regular surveys/ only occasionally	
		Hazard monitoring	are landlsides adequately monitored?	binary; quality and density of monitoring devices	yes/no; expert judgement	
		Connection of weather and rainfall monitoring connection to forecasting models	existence and quality of early warning systems for predictable landslides types	binary; expert judgement upon the quality of models; back analysis	yes/no; match of monitored data to forecasting models	
		Structural defence measures	existance and quality of structural defences/drainage works	binary; expert judgement; movement status	yes/no; quality of defences; state of maintenance	
Built environment	*Exposure and vulnerability of built environment*	Inclusion of vulnerability and exposure assessments in land use plans	Vulnerability assessment of exposed built stock	binary; updating frequency	yes/no; any time new buildings are built/only occasionally	
			Risk maps and scenarios, including enchained events	binary	yes/no	
			Vulnerability and exposure assessment considered in ordinary plans (example land use)	binary; mode of inclusion	yes/no; only formally/substantially with limitations and specific requirements	
	Rules and tools for risk mitigation	Availability, quality and efficacy of mitigation rules	Building codes/rules	binary;attempt to correlate between buildings characteristics and damage due to landslides	yes/no; taking/not taking into account damage accounting in specific databases	
			Traditional building practice based on hazard knowledge	binary; capacity to re-produce traditional techniques correctly	yes/no; judgement about the capacity to conform to the "code of practice"	
			Maintenance of building stock	degree	good/average/poor	
			Land use plans embedding risk mitigation and vulnerability reduction	binary; sectoral/comprehensive; specific/generic	yes/no; expert judgement	
			Integration to other measures (insurance)	binary	yes/no	
Infrastructure and production sites	*Critical infrastructures*	Existence of vulnerability assessments for critical facilities; level of consideration of vulnerability in programs regarding critical facilities	Vulnerability assessment of critical infrastructure	binary ; updating frequency	yes/no; each time new projects are drawn/only occasionally	
			Maintenance programs embedding mitigation	binary ; updating frequency	yes/no	
			New projects based on hazard/risk assessment	binary	yes/no	
			Level of coordination among stakeholders	degree	low/medium/high	
	Production sites	Existence of vulnerability assessments for production sites; consideration of na-techs	Vulnerability assessment of production sites	binary ; updating frequency	yes/no; each time new plants or transformation of existing ones occurs	
			Retrofitting measures for existing production sites	binary	yes/no	
			New projects based on risk assessment	binary	yes/no; special provisions for hazardous plants/generic rules	
			Na-tech explicitly accounted for in hazardous installations emergency plans	binary; expert judgement on quality	yes/no; good/poor quality	
Social system (agents)	*People/individuals*	Capacity of individuals living in prone hazard areas of coping with hazardous events	Risk perception/ awareness	degree	inexistant/average/good	
			Early warning systems	information addressing all components of communiy(ies)	% of coverage	
			Individual preparedness	availability of masks and sholves	yes/no	
			Known evacuation procedures	binary; training	yes/no; training every few years/ only occasionally	
	Community and Instituions	Involvement of a community into decision-making processes related to risk prevention and mitigation, the capacity of Instituions of improving risk awarenees and the level of cooperation among different institutions in charge of risk prevention/ mitigation.	Participation in development and prevention/mitigation strategies	degree	low/average/high	
			Education programs & media campaigns	binary; frequency	yes/no; every two years/only occasionally	
				embedded in school programs	yes/no; every two years/only occasionally	
			Coordination and cooperation among institutions in charge of risk prevention/ mitigation	degree	low/average/high	
	Economic stakeholders	Economic capacity to mitigate of the various stakeholders; the access to financial resources for mitigation	GDP; GVA (Gross added value, measure of productivity and size of economy)	level	rich/average/poor country	
			extent of marginalized groups	dimension of poverty/marginalization	percentage of people living with less than x/year	

Matrix to assess mitigation capacity to landslides

Risk: Landslides **Second Matrix: Physical vulnerability: Vulnerability to stress (hazard)**

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters value/categories	types of landslides					Scoring
						slow movement		rapid movement			
						lateral slide	rotational/translational slide	debris flows	mudflows	rock falls	
Natural environment	*Natural ecosystems*	Fragility of natural ecosystems to hazard(s)	presence of vegetation and forests on sliding slopes	binary; coverage and type	yes/no; % and type	0.5	0.5	1	1	0	
		Possibility of enchained effects due to the interaction of natural systems with the triggering hazard	slope morphology	channels	spread/rare; depth			1	1	0	
		Vulnerability of ecosystems to mitigation measures taken during emergency	presence of ecosystems that may be endangered by lava flows deviations	binary; type	yes/no; type of vegetation and other species	1	1	1	1		
Built environment	*Exposure and vulnerability of built environment*	Factors that make buildings, the urban fabric and public facilities vulnerable to the stress	roof	connection to structure	good/poor						
				shape	large inclination/plane					1	
			structure	material	steel, reinforced concrete, masonry (different types), other			1	1	1	
				type of connection among parts	good/poor	0.5	0.5	0.5	0.5	0.5	
			foundation	depth and type	non-existent, deep, superficial	1	1	1	1	1	
			spans between resistant elements	distance in m.	> 3 mt; < 3 mt (for masonry mainly)	0.5	0.5	0.5	0.5	0	
			shape	openings	number and dimension of windows/doors	0	0	1	1	0	
				quality of openings	may be easily sealed/not	0	0	1	1	0	
			maintenance	building conditions	very poor/ good	1	1	1		1	
				with respect to dangerous channels	parallel/perpendicular	0	0	1	1	0	
				position with respect to the moving mass	on the movement mass/below/below at a distance/ lateral	1	1	1		1	
			Vulnerability assessment of public facilities	as for buildings							
			Vulnerability of the urban fabric	?							
Infrastructure and production sites	*Critical infrastructures*	Factors that make critical infrastructures vulenrable (mainly lifelines	electricity and communication	position of lines with respect to the mass movement	across the moving mass/below/lateral	1	1	1	1	1	
				power station, telecom centre	see buildings assessment	1	1	1	1	1	
			gas	position of gas conducts	across the moving mass/below/lateral	1	1	1	1	1	
				connection to vulnerable buildings	vulnerable buildings/not vulnerable)	1	1	1	1	0	
			water and sewerage	position of water pipes	across the moving mass/below/lateral	1	1	1	1	1	
				pipes condition	across the moving mass/below/lateral						
			road and railways network	position with respect to the moving mass	across the moving mass/below/lateral	1	1	1	1	1	
				defence walls/grids	weak/resistant (material, type, shape); state of maintenance good/poor	1	1	1	1	1	
			tracks and ski runs	position with respect to the moving mass	across the moving mass/below/lateral	1	1	1	1	1	
		What are the factors that make production sites vulnerable	as for buildings								
Social system (agents)	*People/individuals*	Factors that may lead to injuries and fatalities	Preparedness	prior training and exercises; information about what do do	yes/no; frequency of training	1	1	1	1	1	
			Evacuation plan	binary and quality	yes/no; expert judgement	1	1	1 (only with meteo alert)	1 (only with meteo alert)	0	
			Age; mobility impairment, other impairment	difficulties to comply with evacuation orders; difficulties in escaping	yes/no; number of people	0	1	1	1	0	
	Community and Instituions	Factors that may lead to large number of victims	concentration	resident and present population in dangerous areas	presence with respect to the moving mass	1	1	1		1	

Matrix to assess physical vulnerability to landslides

Risk: Landslides **Third Matrix: Systemic vulnerability: Vulnerability to losses**

System	Component	Aspect	Parameters parameters	Criteria for assessment	Parameters values/categories	types of landslides: slow movement	types of landslides: rapid movement	Scoring
Natural environment	*Natural ecosystems*	Fragility of ecosystems to potential secondary effects of hazard(s)	presence of forests/vegetation in denuded slopes	binary and extent	yes/no; types and % of coverage	1	1	
		Vulnerability of ecosystems to mitigation measures taken during emergency	presence of forests and ecosystems in the path where structural works have to be built	binary	yes/no; types and % of coverage	1	1	
Built environment	*Exposure and vulnerability of built environment*	Factors that make buildings, the urban fabric and public facilities vulnerable to losses	Existance of public facilities: hospitals, fire brigades, emergency control rooms	yes/no; functional capacity of such facilities	assessment of functional potential of facilities	0	1	
			Range of service of public facilities	Importance of facilities in the potentially stricken areas	Local facilities/regional/national relevance	1	1	
Infrastructure and production sites	*Critical infrastructures*	Factors that make critical infrastructures stop functioning	Existance of lifelines	binary	yes/no	1	1	
			Degree of interdependance among lifelines	level of redundancy; binary	large redundancy; emergency devices exist/do not; autonomous capacity exist/does not	1	1	
			Continuity plan for lifelines, individually and in a coordinated fashion	binary	yes/no; considers all potential threats/does not	1	1	
			Degree of dependance of critical public facilities from lifelines	binary	autonomous plants exist/do not; alternative resources available/not available	1	1	
			People and areas depending on lifelines in potentially affected zones	number/area dimension	number of customers who may be affected; geographic area	1	1	
			Availability of personnel and spare materials for quick repairs	binary	yes/no	1	1	
			Duration of outages	hours	few hours/> 24	1	1	
		Accesibility to and within vulnerable areas	accessibility from/to damaged areas	to strategic facilities	more than 1 access/1 access/0 access	1	1	
				physical vulnerability of access ways	vulnerable/not vulnerable	1	1	
				condition and features of access ways	narrow/large (> or < 12 mt); inclination (> or < 3%), twisting and curves (yes/no), material (asphalt/not asphalt)	1	1	
			internal accessibility	in residential areas	more than 1 access/1 access/0 access	1	1	
				physical vulnerability of access ways	vulnerable/not vulnerable	1	1	
				condition and features of access ways	narrow/large (> or < 12 mt); inclination (> or < 3%), twisting and curves (yes/no), material (asphalt/not asphalt)	1	1	
			availbility of personnel and means for quick reopening	binary; distance in hours to be covered by personnel and means	yes/no; x < = 2h/ x> 2h	1	1	
	Production sites	Factors that make production sites vulnerable	Degree of dependance of production sites from lifelines	binary; degree of presence of autonomous devices	yes/no; %	1	1	
			Accessibility to the plant and to markets	see internal and particulary external accessibility of the area		1	1	
			Contingency plan for na-tech	binary	yes/no; considers all potential threats/does not	1	1	
			Business continuity plan	binary	yes/no	1	1	
Social system (agents)	*People/individuals*	Factors that may lead to injuries and fatalities	information on risk	degree	enough/sufficient/none	1	1	
			trust in authorities	binary	yes/no	1	1	
	Community and Instituions	Factors that may hamper effective crisis management	continuouing monitoring	binary	yes/no	1	1	
			available equipments	binary	yes/no	1	1	
			potable water storage	binary	yes/no	1	1	
			civil protection plan	binary	yes/no	1	1	
			training and exercise	degree	frequent/not frequent; involving the population /not involving	0.5	1	
			communication plan (multilingual)	binary	yes/no	1	1	

Matrix to assess systemic vulnerability to landslides

Risk: Landslides **Fourth Matrix: Resilience: response capability in the long run**

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters values and/or categories	Comments
Natural environment	*Natural ecosystems*	Ecosystems capacity to recover from damages	Type of forests damaged by landslide	depending on vegetation characteristics		
		Ecosystems capacity to recover from secondary negative effects of emergency mitigation measures	Type of forests damaged by landslide	depending on vegetation characteristics		
		Structural defences	Consolidation and drainage works	binary	feasible/not feasible; funding mechanisms in the reconstruction program	
			Defense grids	binary/funding	can be built/cannot be built; funding mechanisms in the reconstruction program	
Built environment	*Exposure and vulnerability of built environment*	Urban fabric/built environment capacity to recover reducing pre-event vulnerability	New development and reconstruction programs include risk prevention as an everyday activity	degree	yes/partially/no	
			Detailed analysis of damage	degree and scale	yes/partially/no; at individual building/neighborhood/municipal scale	
			Lessons from landslides impact is considered for new construction and retrofitting	degree	yes/partially/no	
			Availability of partial relocation programs during reconstruction for the most critical situations	binary	yes/no	
			Relevance of potentially affected settlements in geographic/economic terms	degree of relevance	Central/peripheral	
Infrastructure and production sites	*Critical infrastructures*	Availability of tools to recover critical infrastructures rapidly and at low costs	Computerized mapping systems of infrstructures	binary	yes/no	
			In site devices for quick survey of damaged parts	binary	yes/no	
			Availability of personnel and spare materials for repairs	binary; time needed to bring on site spare materials	yes/no; < a day/>1 day	
			Existance of protocols to proceed with repairs requiring inter-lifelines interventions	degree; number of different stakeholders to be coordinated in repair efforts	yes/partially/no; protocols among all companies or coordinated by authorities/limited agreements	
			Lessons from landslides impact is considered for lifelines repair	degree	yes/partially/no	
	Production sites	Availability of tools to recover production sites rapidly and at low costs	Temporary transferability of production in case of need	binary	applicable/not applicable	
			Existance of funds for fast repairs	binary	yes/no	
			Existance of inspection and guiding personnel for correct repairs	binary	yes/no/forecasted in the recovery plans	
Social system (agents)	*People/individuals*	People's resilience in the face of the catastrophe induced trauma	Availability of private resources to resettle/repair	binary and level of support by public organisations	yes/no; higly supported/lack of advisory personnel	
			Access to insurance	binary; percentage of coverage	yes/no; %without insurance	
	Community	Affected community's resilience to the consequences of a catastrophe	Employment rate	degree	high/medium/low	
			Annual population growth rate (over the last five years)	trend	high/medium/low/negative	
			Immigration index	new immigrants/emigrants	high/medium/low/negative	
			Social networking	qualitatie judgement	high/medium/low/negative	
			Criminality rate	degree	high/medium/low	
			Conflict among social/ethnic groups	degree	high/medium/low	
			Condition of affected part of the community with respect to the wider provincial context	degree	strongly connected/integrated/marginalized	
	Institutions	Transparency, reliability and trustability of institutions in charge of reconstruction	Degree of trust in institutions	degree	high/medium/low (from sociological surveys when available)	
			Transparency in funds allocation	binary	Existance (yes/no) of public information and independent control mechanisms	
			Capacity to pursue mitigation strategies	Degree	yes/onlypartially/no	
	Economic stakeholders	Capacity and willingness of stakeholders to reinvest in affected areas	Insurance coverage for direct damage and loss of workdays	binary; percentage of coverage	yes/no; %without insurance	
			Dependance of economic actors on loss of environmental goods	Prevalent tourist acitvity; agricoltural activity	percentage	

Matrix to assess resilience to landslides

Risk: volcanic **First Matrix: Resilience: Mitigation capacity**

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters values and/or categories	Comments
Natural environment	*Natural Hazards*	Natural hazards identification and mapping	Volcanic hazard maps availability	binary; scale of detail	yes/no; local/regional	
		Available knowledge updating	Hazard maps updating	Frequency of updating	any time new knowledge is available/ any time activity changes/ only occasionally	
		Hazards monitoring	are volcanic hazards adequately monitored?	binary; quality and density of monitoring devices	yes/no; expert judgement	
		Integration of detection and monitoring systems with forecasting models	existence and quality of volcanic hazards monitoring systems	binary; expert judgement upon the quality of models; back analysis	yes/no; match of monitored data to forecasting models	
			are there early warning systems?	binary	yes/no	
		Structural defence measures			yes/no; quality of defences; state of maintenance	
Built environment	*Exposure and vulnerability of built environment*	Inclusion of vulnerability and exposure assessments in land use plans	Vulnerability assessment of exposed built stock	binary; updating frequency	yes/no; any time new buildings are built/only occasionally	
			Risk maps and scenarios, including enchained events	binary	yes/no	
			Vulnerability and exposure assessment considered in ordinary plans (example land use)	binary; mode of inclusion	yers/no; only formally/substantially with limitations and specific requirements	
	Rules and tools for risk mitigation	Availability, quality and efficacy of mitigation rules	Building codes/rules	binary; expert judgement	yes/no; taking into account new knowwledge and info/only occasionally updated	
			Traditional building practice based on hazard knowledge	?		
			Land use plans embedding risk mitigation and vulnerability reduction	binary; expert judgement	yes/no; sectoral/comprehensive; specific/generic	
			building codes/rules	binary; frequency of inspections; availability of trained personnel for inspections	yes/no; frequent/rare; yes/no and number/total of construction sites every year	
			Integration to other measures (insurance)	binary	yes/no	
Infrastructure and production sites	*Critical infrastructures*	Existence of vulnerability assessments for critical facilities; level of consideration of vulnerability in programs regarding critical facilities	Vulnerability assessment of critical infrastructure	binary ; updating frequency	yes/no; each time new projects are drawn/only occasionally	
			Maintenance programs embedding mitigation	binary ; updating frequency	yes/no	
			New projects based on hazard/risk assessment	binary	yes/no	
			Level of coordination among stakeholders	degree	low/medium/high	
	Production sites	Existence of vulnerability assessments for production sites; consideration of na-techs	Vulnerability assessment of production sites	binary ; updating frequency	yes/no; each time new plants or transformation of existing ones occurs	
			Retrofitting measures for existing production sites	binary	yes/no	
			New projects based on risk assessment	binary	yes/no; special provisions for hazardous plants/generic rules	
			Na-tech explicitly accounted for in hazardous installations emergency plans	binary; expert judgement on quality	yes/no; good/poor quality	
Social system (agents)	*People/individuals*	Evaluation of the capacity of individuals living in prone hazard areas of coping with hazardous events	Risk perception/ awareness	degree	inexistant/average/good	
			Early warning systems	information addressing all components of communiy(ies)	% of coverage	
			Individual preparedness	availability of masks and sholves	yes/no	
			Known evacuation procedures	binary; training	yes/no; training every few years/ only occasionally	
	Community and Instituions	Involvement of a community into decision-making processes related to risk prevention and mitigation, the capacity of Instituions of improving risk awarenees and the level of cooperation among different institutions in charge of risk prevention/ mitigation.	Participation in development and prevention/mitigation strategies	degree	low/average/high	
			Education programs & media campaigns	binary; frequency	yes/no; every two years/only occasionally	
				embedded in school programs	yes/no; every two years/only occasionally	
			Coordination and cooperation among institutions in charge of risk prevention/ mitigation	degree	low/average/high	
	Economic stakeholders	Level of preparedness of key economic stakeholders	GDP; GVA (Gross added value, measure of productivity and size of economy)	level	rich/average/poor country	
			extent of marginalized groups	dimension of poverty/marginalization	percentage of people living with less than x/year	

Matrix to assess mitigation capacity to volcanic risk

Risk: Volcanic **Second Matrix: Physical vulnerability: Vulnerability to stress (hazard)**

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters value/categories	Relevance with respect to volcanic hazards						Score
						gas	tephra	pyroclastic flows	ballistic	lava flows	lahars	
Natural environment	*Natural ecosystems*	Fragility of natural ecosystems to hazard(s)	presence of vegetation and forests on the volcanic slopes	binary; coverage and type	yes/no; % and type			1	0.5	1	1	
		Possibility of enchained effects due to the interaction of natural systems with the triggering hazard	type of soil; vegetation	rock/varioustypes of loose soil; trees with long and extended roots/no vegetation or with superficial roots	qualitative	0	0.5			1	-	
		Vulnerability of ecosystems to mitigation measures taken during emergency	presence of ecosystems that may be endangered by lava flows deviations	binary; type	yes/no; type of vegetation and other species	0			0	1		
Built environment	*Exposure and vulnerability of built environment*	Factors that make buildings, the urban fabric and public facilities vulnerable to the stress	Vulnerability assessment of public facilities	internal machinery sensitive to the volcanic hazards	yes/no; type of machinery		0.5	1		1	1	
			Average vulnerability at the municipal scale, considering settlements or urban partitions	Considering parameters provided in the attached specific table	Low-medium-high vulnerability	1	1	1	1	1	1	
Infrastructure and production sites	*Critical infrastructures*	Factors that make critical infrastructures vulenrable (mainly lifelines)	electricity and communication	lines	aerial lines/underground			1			1	
				power station, telecom centre	see buildings assessment		1	1	1		1	
			gas	position of gas conducts	across hazardous zones		1	1			1	
				connection to buildings	vulnerable buildings/not vulnerable)							
			water and sewerage	position of water pipes	across hazardous zones		1 (across landslide)				1	
				pipes condition	obsolete/new							
			position	distance from dangerous areas	inside/outside potentially affected areas (scenario dependent)		1	1			1	
			point shaped elements	bridges	weak/resistant (material, type,		1(debris	1	1		1	
		Factors that make production sites vulnerable	presence of flammable materials	binary; amount	yes/no; quantities							
Social system (agents)	*People/individuals*	Factors that may lead to injuries and fatalities	Preparedness	prior training and exercises; information about what do do	yes/no; frequency of training	1	1	need to be evacuated	need to be evacuated		need to be evacuated	
			Sensistivity to health effects of volcanic hazards	means of self protection	yes/no;	1	1	-	-	-	-	
			Age; mobility impairment, other impairment	difficulties to comply with evacuation orders; difficulties in escaping	yes/no; number of people	0.5	0.5	1	1	1	1	
	Community and Instituions	Factors that may lead to large number of victims	concentration	resident and present population in dangerous areas	inside/outside potentially affected areas (scenario dependent)	1	1	1	1		1	

Matrix to assess physical vulnerability to volcanic risk

Aspect	Aspect Parameters	Criteria for assessment	Parameter value /categories	gas	tephra	pyroclastic flows	ballistic	lava flows	lahars
Factors that make buildings and public facilities vulnerable to the stress	Vulnerability assessment of residential buildings and public facilities	roof	connection to structure	good/poor		1		1	
			weight	heavy/light		1			
			shape	large inclination/plane		1 (pitch > 15° ok)		0.5	
		structure	material	iron, reinforced concrete, masonry (different types), other		0,5 (worse: timber)	0,5 (best: r.c, masonry if homog. resistance; worse: timber)		
			homogeneity	large/largely disomogenous		1	1	1	
			type of connection among parts	good/poor		0.5	0.5	0.5	0.5
			floors rigidity	rigid/non rigid					
		foundation	depth and type	non-existent, deep, superficial			1		1
		spans between resistant elements	distance in m.	> 3 mt; < 3 mt (for masonry mainly)		0.5			
		shape	openings	number and dimension of windows/doors	1	1	1		0.5
			quality of openings	may be easily sealed/not	1	1	1		
			basement	existant/non existant	1				
			inflammable objects	existant/non existant	1	0.7	0.7	0.5	0.5
			sources of radiation or toxic chemicals	existant/non existant					
		maintenance	building conditions	very poor/ good		1	1	1	1
		position	soil on which the building is built (crest, alluvial deposits, etc.)	amplification soils yes/no	0.5				
			with respect to dangerous channels	parallel/perpendicular			1		1
			distance from dangerous areas	inside/outside potentially affected areas (scenario dependent)	0.5	0.5	1	1	1

Matrix to assess physical vulnerability of built environment to volcanic risk

Risk: volcanic **Third Matrix: Systemic vulnerability: Vulnerability to losses**

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters values and/or categories	Scoring
Natural environment	*Natural ecosystems*	Fragility of ecosystems to potential secondary effects of hazard(s)	induced lahars; induced landslides	binary; extent	yes/no; maps	
		Possibility of enchained effects due to the interaction of natural systems with the triggering hazard		meteorological assessment in the days after the initial crisis	rainy/dry	
		Vulnerability of ecosystems to mitigation measures taken during emergency	presence of forests and ecosystems in the path where lava flows are going to be deviated	binary	yes/no; types and % of coverage	
Built environment	*Exposure and vulnerability of built environment*	Factors that make buildings, the urban fabric and public facilities vulnerable to losses	Quality of temporary shelters (first emergency)	with heating or conditioning; sanitation; density	yes/no; a>1/50 people/ a < 1/50 people; d < 1tent per family/d > 20 persons/tent	
			Quality of more permenent temporary shelters	dimension; availability of services	d > 14 mq/4 persons/ d < 10 mq/4 persons; yes/no	
			Accessibility to potentially damaged areas from temporary shelters	on foot; transportation	d < 500 m/ d> 500 m; available/not available; frequent/not frequent	
			Accessibility to work sites from temporary shelters	on foot; transportation	d < 500 m/ d> 500 m; available/not available; frequent/not frequent	
			Accessibility to public facilities	on foot; transportation	d < 500 m/ d> 500 m; available/not available; frequent/not frequent	
Infrastructure and production sites	*Critical infrastructures*	Factors that make critical infrastructures stop functioning	gas, water, electricity, telecom	existence and redundancy	more than 1/ 1/ 0	
				fucntional vulnerability to physical damage (physical vulnerability)	vulnerable components crucial for functioning: yes/no	
				dependency from other systems	dependent/autonomous	
			internal accessibility	to strategic facilities	more than 1 access/1 access/0 access	
				physical vulnerability of access ways	vulnerable/not vulnerable	
				condition and features of access ways	narrow/large (> or < 12 mt); inclination (> or < 3%), twisting and curves (yes/no), material (asphalt/not asphalt)	
				in residential areas	more than 1 access/1 access/0 access	
				physical vulnerability of access ways	vulnerable/not vulnerable	
				condition and features of access ways	narrow/large (> or < 12 mt); inclination (> or < 3%), twisting and curves (yes/no), material (asphalt/not asphalt)	
			external accessibility	heliports	existent/non existent	
					accessibility from settlements (as accessiblity to strategic facilities)	
					physical vulnerability (as roads position parameter)	
					gathering zones close	
				ports	existent/non existent	
					accessibility from settlements (as accessiblity to strategic facilities)	
					physical vulnerability (as roads position parameter)	
					gathering zones cloes	
	Production sites	Factors that may lead to halting production	Degree of dependance of production sites from lifelines	binary; degree of presence of autonomous devices	yes/no; %	
			Accessibility to the plant and to markets	see internal and particulary external accessibility of the area		
			Contingency plan for na-tech	binary	yes/no; considers all potential threats/does not	
			Business continuity plan	binary	yes/no	
Social system (agents)	*People/individuals*	Factors that may reduce coping capacity during crisis	self protection means	yes/no	1 (masques)	1 (shovels)
			information on risk	enough/sufficient/none	1	1
			trust in authorities	yes/no	1	1
	Community and Institutions	Factors that may hamper effective crisis management	permanent staff	yes/no	1	1
			continuouing monitoring (>weight if early warning possible)	yes/no	1	0.5
			available equipments	yes/no	1 (masques)	1 (drill)
			potable water storage	yes/no	1	1
			civil protection plan	yes/no	1	1
			training and exercise	frequent/not frequent; involving the population /not involving	1	1
			communication plan (multilingual)	yes/no	1	1

Matrix to assess systemic vulnerability to volcanic risk

Risk: volcanic **Fourth Matrix: Resilience: response capability in the long run**

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters values and/or categories	Scoring
Natural env.	*Natural ecosystems*	Ecosystems capacity to recover from damages	can it be as ofr fires?			
		Ecosystems capacity to recover from secondary negative effects of emergency mitigation measures	can it be as ofr fires?			
Built environment	*Exposure and vulnerability of built environment*	Urban fabric/built environment capacity to recover reducing pre-event vulnerability	Temporary transferability of facilities relevant for the settlement/city community life and economy	binary; type of relocation	yes/no; temporary/permanent	
			Existance of plans for reconstruction in case of severe destruction scenarios	binary	yes/no	
			Level of sharing among stakeholders of reconstruction plans	degree	High/low; only formal/substantial	
			Level of integration of physical reconstruction with community healing processes	degree	High/low; room for interpreting in the new/restored setting the meaning of the destruction	
			Relevance of potentially affected settlements in geographic/economic terms	level of importance	Central/peripheral	
Infrastructure and production sites	*Critical infrastructures*	Availability of tools to recover critical infrastructures rapidly and at low costs	Computerized mapping systems of infrstructures	binary	yes/no	
			In site devices for quick survey of damaged parts	binary	yes/no	
			Availability of spare materials for fast repairs	binary; time needed to bring on site spare materials	yes/no; t < 1 day/ several days	
			Availability of personnel for repairs	location and number of technicians	on site/in distant areas; number of available technicians with respect to expected need	
			Existance of protocols to proceed with repairs requiring inter-lifelines interventions	degree; number of different stakeholders to be coordinated in repair efforts	yes/partial/no; one main stakeholder/several stakeholders	
	Production sites	Availability of tools to recover production sites rapidly and at low costs	Temporary transferability of production in case of need	binary	applicable/not applicable	
			Existance of funds for fast repairs	binary	yes/no	
			Existance of inspection and guiding personnel for correct repairs	binary	yes/no/forecasted in the recovery plans	
			Economic sectors	Diversified or concentrated on few sectors	Few/many different economic sectors in the area	
Social system (agents)	*People/individuals*	People's resilience in the face of the catastrophe induced trauma	Availability of psychological support for adults and children	binary	yes/no	
			Availability of private resources to resettle/repair	binary; support by public agencies; rapidity of compensation process	yes/no; available/not available; rapid/slow	
			Access to insurance	binary and coverage	yes/no; percentage of coverage	
	Community	Affected community's resilience to the consequences of a catastrophe	Age structure	Areas vitality	Aging population; low fertility rates	
			Local condition of aged population	binary	autonomous/not autonomous; relatively healthy/not healthy	
			Employment rate	degree	high/medium/low	
			Annual population growth rate (over the last five years)	degree	high/medium/low/negative	
			Immigration index	degree	high/medium/low/negative	
			Social networking	degree	high/medium/low/negative	
			Criminality rate	degree	high/medium/low	
			Conflict among social/ethnic groups	degree	high/medium/low	
	Institutions	Transparency, reliability and trustability of institutions in charge of reconstruction	Degree of trust in institutions	degree	high/medium/low (from sociological surveys when available)	
			Transparency in funds allocation	Existance of public information and independent control mechanisms	yes/no	
			Long term vision	Existance of strategic development/land use plans	yes/no	
	Economic stakeholders	Capacity and willingness of stakeholders to reinvest in affected areas	Insurance coverage	binary and coverage	Yes/no;percentage	
			Construction industry	level of development and modernization	high/average/low	

Matrix to assess resilience to volcanic risk

Risk: seismic **First Matrix: Resilience: Mitigation capacity**

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters values and/or categories	Application or comments from case studies
Natural environment	*Natural Hazards*	Natural hazards identification and mapping	Hazard mapsincluding map for fault rupturing at the ground surface availability	At the following scales: country level; regional and provincial; lower scales	yes/no; quality as judged with respect to international standards and updated to new knowledge and technologies	In the Alaska case (earthquake 1964) geological hazards connected to seismic were well known and mapped, though not embedded in metropolitan master plans of Anchorage for example
			Geological map of quaternary formation			
			Map of topographic amplification zones			
		Hazard monitoring	availability of seismographs and accelerometers networks	binary and density	yes/no; dense/only individual sparse points	In Italy before the 70s the seismograph and accelerometers networks were significantly underdeveloped/absent in several zones
		Induced/triggered hazards consideration in hazard monitoring systems	Availability of maps of landslides and estimation of their potential movement consequent to earthquakes	binary; quality	yes at appropriate scale/no; quality with resepct to international standards	Induced and triggered hazards have been the object of study only recently; many regions though have developed such knowledge in the last ten/15 years
			Map of potential liquefaction zones	binary; coverage	yes/no; only spot like/covering the entire area of concern	
			Map of tsunami hazard	binary	yes/no	
			Tsunami monitoring network	binary	yes/no	
Built environment	*Exposure and vulnerability of built environment*	Is exposure and vulnerability considered and acted upon in plans?	Vulnerability assessment of exposed built stock	binary; frequency	yes/no; updated at the same rate of urban growth/not updated	In Italy for example extensive vulnerability survey campaings have been carried out in several regions
			Risk maps and scenarios, including enchained events	binary	yes/no	
			Vulnerability and exposure assessment considered in ordinary plans (example land use)	binary; mode of inclusion	yes/no; only formally/substantially with limitations in amplification zones and specific building requirements	Unfortunately available vulnerability assessment, including the assessment of all public buildings vulnerability in Southern regions is not considered in development/restoration plans in the majority of Italian regions
	Rules and tools for risk mitigation	Inclusion of vulnerability and exposure assessments in land use plans	Building codes/rules	binary; quality	yes/no; updated according to state of the art/old	Various cases, like the Kocaeli earthquake have shown the importance of cosndiering the year when building codes were issued
			Traditional building practice based on hazard knowledge	binary; capacity to re-produce traditional techniques correctly	binary; judgement about the capacity to conform to the "code of practice"	Expertise has been developed in Italy for example regarding the issue of "code of practice" connecting traditional local knowledge and earthquake resistance capacity; provisions for retrofitting have been attached to the financial law after earthquakes
			Maintenance of built stock	binary	yes/no	
			Specific provisons for retrofitting	binary	economic incentives promoted/not promoted	
			Land use plans embedding risk mitigation and vulnerability reduction	binary/ expert quality judgement	yes/no; sectoral/comprehensive; specific/generic	
			Implementation capacity	binary; frequency of inspections; availability of trained personnel for inspections	yes/no; frequent/rare; yes/no and number/total of construction sites every year	In several recent earthquakes (Gujarat, 2001; Turkaey, 1999; Algeria, 2003; L'Aquila 2009 poor compliance was one of the main casuses of recent buildings failure
			Integration to other measures (insurance)	binary	yes/no	Only in Turkey after the 1999 earthquake the program funded by the World Bank connects insurance to antiseismic development
Infrastructure and production sites	*Critical infrastructures*	Existence of vulnerability assessments for critical facilities; level of consideration of vulnerability in programs regarding critical facilities	Vulnerability assessment of critical infrastructure	binary ; updating frequency	yes/no; each time new projects are drawn/only occasionally	Relevant in California
			Maintenance programs embedding mitigation	binary ; updating frequency	yes/no	In California there is a tradition that permitted the seismic upgrading of lifelines in ordinary maintenance and new projects
			New projects based on hazard/risk assessment	binary	yes/no	
			Level of coordination among stakeholders	degree	low/medium/high	
	Production sites	Existence of vulnerability assessments for production sites; consideration of na-techs	Vulnerability assessment of production sites	binary ; updating frequency	yes/no; each time new plants or transformation of existing ones occurs	
			Retrofitting measures for existing production sites	binary	yes/no	
			New projects based on risk assessment	binary	yes/no; special provisions for hazardous plants/generic rules	
			Na-tech explicitly accounted for in hazardous installations emergency plans	binary; expert judgement on quality	yes/no; good/poor quality	
			Existance of emergency plans that explicitly take into account erthquakes as threat to be prepared for	binary; expert judgement on quality	yes/no; good/poor quality	
Social system (agents)	*People/individuals*	Capacity of individuals living in prone hazard areas of coping with hazardous events, which largely depends on the perception and awareness of risk conditions	Risk perception/ awareness	degree	inexistant/average/good	
			Individual preparedness	regarding specific self protective measures; regarding measures included in emergency plans	low/average/high	Even in Kobe the individual preparedness proved to be poor despite national programs; few people had radio working with batteries; few had a bottle of water and basic commodities ready for evacuation
	Community and Instituions	Evaluation of the involvement of a community into decision-making processes related to risk prevention and mitigation, the capacity of Instituions of improving risk awarenees through information and education campaigns and the level of cooperation among different institutions in charge of risk prevention/ mitigation.	Participation in development and prevention/mitigation strategies	degree	low/average/high	
			Education programs & media campaigns	binary; frequency	yes/no; every two years/only occasionally	
				embedded in school programs	yes/no; every two years/only occasionally	
			Coordination and cooperation among institutions in charge of risk prevention/ mitigation	degree	low/average/high	
	Economic stakeholders	Economic capacity to mitigate of the various stakeholders; the access to financial resources for mitigation	GDP; GVA (Gross added value, measure of productivity and size of economy)	level	rich/average/poor country	
			extent of marginalized groups	dimension of poverty/marginalization	percentage of people living with less than x/year	

Matrix to assess mitigation capacity to seismic risk

Risk: seismic **Second Matrix: Physical vulnerability: Vulnerability to stress (hazard)**

	System	Aspect	Parameters	Criteria for assessment	Descriptors	Application or comments from case studies
Natural ec	*Natural ecosystems*	Fragility of natural ecosystems to hazard(s)	extent of potentially flooded zones by tsunami	degree and relevance of impacted zones	extended areas/few zones; urban areas impacted/remote areas	
			extent and location of triggered landslides	degree and relevance of impacted zones	extended areas/few zones; urban areas impacted/remote areas	
Built environment	*Exposure and vulnerability of built environment*	Factors that make buildings, the urban fabric and public facilities vulnerable to the stress	Average vulnerability at the municipal scale, considering settlements(rural) or urban parts	Considering parameters provided in the attached specific table	Low-medium-high vulnerability	
			Vulnerability assessment of historic buildings/monuments	Specific vulnerability indicators depending on the type of building/structure	Low-medium-high vulnerability	
			Vulnerability assessment of public facilities	as for residential buildings		
				internal machinery vulnerable to shakes	yes/no; adapted to seismic shaking/not adapted	
			Vulnerability of the urban fabric	vulnerability assessment of structural built aggregates	on the basis of: regularity; presence of strong inclination; presence of structural disomogenity	The urban fabric is not the simple addition of buildings, particularly in historic centres where a set of buildings sharing structural components like walls manifest a rather different behavior to shaking than if the buildings were not connected. This behavior has been surveryed in several earthquakes in Italy and elsewhere
				relationship between built and open areas	large spaces between buidlings and open spaces availble/dense and narrow built zones	
Infrastructure and production sites	*Critical infrastructures*	Factors that make critical infrastructures vulenrable (mainly lifelines	Vulnerability assessment of lifelines	electricity (including nodes like power stations	derived from e.g. network caracteristics (buried/aerial	Earthquake lifelines engineering is a branch of civil and seismic engineering devoted to the understanding of lifelines behavior under shaking and induced stresses (liquefaction, landslides, etc.). First extensive reports go back to the Northridge earthquake in 1994, the Kobe earthquake in 1995 and all following earthquake. Studies are polarized between very technical issues regarding the behavior of individual components, like bridges, valves, joints, pipes on the one hand and the systemic functioning of lifelines on the other.
				communication (including nodes like base transceiver station,...)	derived from e.g. network caracteristics (buried/aerial,!), conditions (age, degree of maintenance), network redundancy	
				gas network (including nodes like production facilities, tank farms, stations,...)	derived from e.g. network caracteristics (rigid/ductile material, existence of shut-off valves/circuit-breakers!), conditions (age, degree of maintenance), network redundancy	
				water, drinking water and sewerage network (including dams, treatment plants, pumping stations, ...)	derived from e.g. network caracteristics (rigid/ductile material, existence of shut-off valves/circuit-breakers!), conditions (age, degree of maintenance), network redundancy	
				transport lines: roads, railways for instance (including bridges, tunnels, embankment/slopes!)	derived from e.g. network caracteristics (type of material, !), conditions (age, degree of maintenance), network redundancy	
			Presence of dams	binary; assessed vulnerability to earthquakes	yes/no; low/medium/high	
			Vulnerability due to physical interaction among lifelines	lifelines degree of connection	low/high	
			Vulnerability due to lifeline connections physical interaction with to vulnerable buildings	lifelines close and attached to resistant/vulnerable buildings	yes/no	
	Production sites	Factors that make production sites vulnerable (including na-tech potential)	Vulnerability assessment of production sites	as for public facilities		Na-tech have been only recently the object of systematic studies; in the seismic field in particular after the Kocaeli earthquake in 1999 where an important refinery exploded and burned as a secondary consequence of the earthquake
			Potential na-tech due to stored materials, types of processes	binary and number of workers, types of processes	yes/no; small/large firms ' processes types	
			Vulnerability due to dependency on lifelines	dependance on lifelines	low/medium/high (existence of alternative solutions)	
Social system (agents)	*People/individuals*	Factors that may lead to injuries and fatalities	People concentration in different zones in the hours of the day	degree of concentration in vulnerble locations/buildings	low/medium/high	The Kobe eartheuake is an example of vulnerable residential buildings where many people died; the Alaska earthquake just the opposite, as many more people would have died were the people working in the central district heavily affected by landlsides
			Preparedness	previous training	yes/no	
			Age; mobility impairment, other impairment	difficulties to comply with evacuation orders; difficulties in escaping	yes/no, number of people	
	Community and Instituions	Factors that may lead to large number of victims	Existance of emergency plan and quality	binary; quality	yes/no; as judged by involved institutions	In several cases the lack of basic SAR tools has casued the increase of victims trapped under debris. Studies show that in the first 24 hours the same victims are the first reponders
			Availability of resources for search and rescue (lamps; cranes, special devices)	binary; number with respect to potentially damaged areas	yes/no; imemdiately accessible/remote; sufficient/not sufficient	

Matrix to assess physical vulnerability to seismic risk

Vulnerability parameters for individual buildings

Aspect	Parameters	Criteria for assessment	Descriptors (in order of higher vulnerability)	weight	score (1=high; 5=very low)	Comments
What are the factors that make buildings and public facilities vulnerable to the stress?	Vulnerability assessment of residential buildings and public facilities	roof connection to the building structure	good/mediocre/poor			Those parameters are quite well established in the international literature, unlike for other hazards. The process of identifying correlations between damage acceleration-vulnerability is quite developed in several countries, with large damage database that permit to identify the main causes of failures of ordinary structures. Special facilities likfe hospitals, theaters, churches hav been less studied and only recent reports permit to establish the vulenrability of special buildings and stored machinery/goods. After the Northridge earthquake some articles report the vulnerability of hospitals and special equipments incuding generators
		roof weight	light/heavy			
		structural material	iron, r.c. antiseismic, timber/masonry/stone,un cooked earth			
		connection among walls and building parts	good/mediocre/poor			
		floors rigidity	flexible/rigid			
		foundation depth and type	deep/superficial/non existent			
		position with respect to soil type	non amplification zones/amplification areas/liquefaction zones			
		spans between resistant elements (mainly masonry)	d < 3 m/d > 3 m			
		openings	part of the structure/create structural discontinuity			
		regularity in plan	regular/asymmetric distribution of forces			
		regularity in elevation	regular/asymmetric distribution of forces			
		added parts (balconies, chimneys)	attached/loosely connected to structure			
		maintenance	good/poor			
		retrofitting programs	available/not available; good/poor			

Matrix to assess physical vulnerability of built environment to seismic risk

Risk: seismic **Third Matrix: Systemic vulnerability: Vulnerability to losses**

System	Component	Aspect	Aspect Parameters	Criteria for assessment	categories	Comments from case studies
Natural environment	*Natural ecosystems*	Fragility of ecosystems to potential secondary effects of hazard(s)	areas affected by landslides	number and extent	few/many; in remote areas/in crucial-central zones	
Built environment	*Exposure and vulnerability of built environment*	Factors that make buildings, the urban fabric and public facilities vulnerable to losses	Availability of rapid post seismic buildings usability assessment	forms pre-prepared and shared among all teams	yes/no	The l'Aquila case showed that the existenc of various forms reduces the efficiency of usability srveys, as well as the lack of comuterized systems for their fast recovery and particularly georeferencing.
				information computerized	yes/no	
				rapid damage assessment map obtained in few weeks	yes/no	
			Quality of temporary shelters (first emergency)	with heating or conditioning; sanitation; density	yes/no; a>1/50 people/ a < 1/50 people; d < 1tent per family/d > 20 persons/tent	The availability of human conditions in temporary camps is essential for peple's recovery, particularly when the earthquake strikes in winter
			Quality of more permenent temporary shelters	dimension; availability of services	d > 14 mq/4 persons/ d < 10 mq/4 persons; yes/no	As temporary shelters in seismic hit zones are expected to last some years, they must be provided with a minimal level of commodities. In the meantime accessibility to working places and homes is essential for victims
			Accessibility to potentially damaged areas from temporary shelters	on foot; transportation	d < 500 m/ d> 500 m; available/not available; frequent/not frequent	
			Accessibility to work sites from temporary shelters	on foot; transportation	d < 500 m/ d> 500 m; available/not available; frequent/not frequent	
			Accessibility to public facilities	on foot; transportation	d < 500 m/ d> 500 m; available/not available; frequent/not frequent	
Infrastructure and production sites	*Critical infrastructures*	Factors that make critical infrastructures stop functioning	Redundancy in lifelines systems	degree	low/high	The capacity to isolate priority nodes for fast recovery of lifelines; the availability of tanks, generators and any other means to make lifelines and critical facilities work at least partially after the event is clearly crucial also for carrying out emergency operations. The Kobe and the Northridge earthquakes showed clearly that such availability is much less available than thought and than what would be required and possibile thanks to modern technologies
			Degree of interdependance among lifelines	degree	low/medium/high	
			Availability of emergency devices	binary (generators; tanks, etc)	yes/no	
			Continuity plan for lifelines, individually and in a coordinated fashion	binary and quality	yes/no; considers also induced hazards/ does not	
			Degree of dependance of critical public facilities from lifelines	degree	low/medium/high	
	Production sites		Degree of dependance of production sites from lifelines	degree	low/medium/high	
			Accessibility to the plant and to markets	redundancy; quality of roads; usability; expected increase in travel time	redundant/not redundant; open/close roads; t.inc < 30 min/ t.inc > 30 min	
			Contingency plan for na-tech	binary	yes/no; considers all potential threats/does not	
			Business continuity plan	binary	yes/no	
Social system (agents)	*People/individuals*	Factors that may reduce coping capacity during crisis	Access to understandable information	binary	yes/no; centralized /at each group level (for example in each temporary camp)	
			Trust in information provisers	degree	low/medium/high	
			Preparedness to evacuation	individual plan	yes/no (like going to relatives)	
			Presence of impaired groups (elderly, sick persons, etc.)	binary and quality of caring	yes/no; capacity to provide treatment in temporary camps/or not	In the l'Aquila case an accurate survey of people needing care for cronic deseases whas conducted and patients were given thier treatment since the first days
	Community and Institutions	Factors that may hamper effective crisis management	Existance of contingency plan fro threats at stake	binary; date of last production or update	yes/no; recent/old	
			availability of quick post event scenarios to be checked and used as a guidance in crisis management	binary and quality	yes/no; considering also enchained effects and systemic damage/restricted to physical damage	Comfort (1999) refers to the Northridge earthquake when repsonders could count on available pre-set scenarios for rapid damage estimation
			Training using the contingency plan	binary; frequency of training	yes/no; every two years/only occasionally	
			Overlapping responsiblities among agencies	degree	Low/medium/high	Overlapping responsibilities between the firemen and other technicians of the civil protection in usability surveys and first shoring have sometimes delayed surveys and return of people to undamaged houses in the l'Aquila case
			Established protocols for information sharing	binary	yes/no	
			Established protocols for use of resources to manage the crisis	degree	yes/only partially/high	

Matrix to assess systemic vulnerability to seismic risk

Risk: seismic **Fourth Matrix: Resilience: response capability in the long run**

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters values and/or categories	Comments from case studies
Built environment	*Exposure and vulnerability of built environment*	Urban fabric/built environment capacity to recover reducing pre-event vulnerability	Temporary transferability of facilities relevant for the settlement/city community life and economy	binary; type of relocation	yes/no; temporary/permanent	In the l'Aquila case all public services located in the historic centre were transferred to the School of the Financial Police in an external quartier nearby. The problem of leaving a centre empty of functions for a long while must be carefully considered
			Existance of plans for reconstruction in case of severe destruction scenarios	binary	yes/no	
			Reconstruction plans considers lessons learnt from earthquake (including amplification zones)	binary and quality	yes/no; seismic zonation map made available for reconstruction/not available	In the Umbria Marche case (1997) provision of compensation was granted on the basis of a seismic zonation map showing the most critical amplification zones
			Existance of skilled workers/firms for repairs and reconstruction (example historic sites)	binary; quality	Yes/no; availability with respect to expected need	In the Umbria Marche case, the lack of firms with workers skilled in the restoration of historic centres and in the meantime seismic retrofitting required careful consideration and creation of technical consultancy by the two regions
			Level of sharing among stakeholders of reconstruction plans	degree	High/low; only formal/substantial	The Umbria Marche case showed a good level of integration between the central government and the two regions.
			Level of integration of physical reconstruction with community healing processes	degree	High/low; room for interpreting in the new/restored setting the meaning of the destruction	
			Relevance of potentially affected settlements in geographic/economic terms	level of importance	Central/peripheral	
Infrastructure and production sites	*Critical infrastructures*	Availability of tools to recover critical infrastructures rapidly and at low costs	Computerized mapping systems of infrstructures	binary	yes/no	The Kobe earthquake has shown that recovery time is strongly connected to the availability of personnel, maps of systems, material for repairs, capacity to handle car traffic in areas where repairs must be carried out
			In site devices for quick survey of damaged parts	binary	yes/no	
			Availability of spare materials for fast repairs	binary; time needed to bring on site spare materials	yes/no; t < 1 day/ several days	
			Availability of personnel for repairs	location and number of technicians	on site/in distant areas; number of available technicians with respect to expected need	
			Existance of protocols to proceed with repairs requiring inter-lifelines interventions	degree; number of different stakeholders to be coordinated in repair efforts	yes/partial/no; one main stakeholder/several stakeholders	
	Production sites	Availability of tools to recover production sites rapidly and at low costs	Temporary transferability of production in case of need	binary	applicable/not applicable	
			Existance of funds for fast repairs	binary	yes/no	
			Existance of inspection and guiding personnel for correct repairs	binary	yes/no/forecasted in the recovery plans	
			Economic sectors	Diversified or concentrated on few sectors	Few/many different economic sectors in the area	
Social system (agents)	*People/individuals*	People's resilience in the face of the catastrophe induced trauma	Availability of psychological support for adults and children	binary	yes/no	In the l'Aquila case provision of psychological support for victims was extensive and helped to solve several problems in temporary tent camps
			Availability of private resources to resettle/repair	binary; support by public agencies; rapidity of compensation process	yes/no; available/not available; rapid/slow	
			Access to insurance	binary and coverage	yes/no; percentage of coverage	
	Community	Affected community's resilience to the consequences of a catastrophe	Age structure	Areas vitality	Aging population; low fertility rates	After the Friuli earthquake in 1976, several centres were rebuilt in areas that had experienced high levels of abandonment: several empty buildings can be found nowadays in the rebuilt zone.
			Local condition of aged population	binary	autonomous/not autonomous; relatively healthy/not healthy	
			Employment rate	degree	high/medium/low	
			Annual population growth rate (over the last five years)	degree	high/medium/low/negative	
			Immigration index	degree	high/medium/low/negative	
			Social networking	degree	high/medium/low/negative	
			Criminality rate	degree	high/medium/low	
			Conflict among social/ethnic groups	degree	high/medium/low	
	Institutions	Transparency, reliability and trustability of institutions in charge of reconstruction	Degree of trust in institutions	degree	high/medium/low (from sociological surveys when available)	
			Transparency in funds allocation	Existance of public information and independent control mechanisms	yes/no	The Friuli earthquake in 1976 was a good example of transparency a sort of collective control over money expenditure was developed; on the contrary the Irpinia reconstruction after the 1980 earthquake was object to several court and parlamentary trials for briberies etc.
			Long term vision	Existance of strategic development/land use plans	yes/no	
	Economic stakeholders	Capacity and willingness of stakeholders to reinvest in affected areas	Insurance coverage	binary and coverage	Yes/no;percentage	
			Construction industry	level of development and modernization	high/average/low	

Matrix to assess resilience to seismic risk

Risk: forest fire **First Matrix: Resilience: Mitigation capacity**

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters values and/or categories	weight	score (1=high; 5=very low)	Scale
Natural environment	*Natural Hazards*	Natural hazards identification and mapping	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		
			Do hazard assessment consider climate change	binary	yes/no	0.5		
		Available knowledge updating	Hazard maps updating	Frequency of updating	every 2 years and after each event/rarely	0.5		
		Hazard monitoring systems	Existence, distribution and quality of monitoring networks	technical monitoring systems linked to operation centre	yes/no	1		
				permanent staff dispaced in critical areas for direct monitoring and immediate intervention	yes/no	0.5		
		Connection of monitoring devices to 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		
		Structural defence measures	Existence of defenses for breaking the fire lines	binary	yes/no	1		
Built environment	*Exposure and vulnerability of built environment*	Inclusion of vulnerability and exposure assessments in land use plans	Vulnerability assessment of exposed built stock	binary; updating frequency	yes/no; every time new building permits are given/only occasionally	1		
			Risk maps and scenarios, including enchained events	binary; year of production	yes/no	1		
			Vulnerability and exposure assessment considered in ordinary plans (example land use)	binary; mode of inclusion	yes/no; only formally/substantially with limitations and specific requirements	1		
	Rules and tools for risk mitigation	Availability, quality and efficacy of mitigation rules	Building codes/rules	binary; updated	yes/no; rules efficacy checked after each event/rarely tested	0.5		
			Property regime of houses	owned houses versus tenants	owners ow < 50%/ ow > 80%	0.5		
			Traditional building practice based on hazard knowledge	binary; capacity to re-produce traditional techniques correctly	yes/no; judgement about the capacity to conform to the "code of practice"	0.5		
			Maintenance of fire suppression devices and clearing vegetation around houses	binary	yes/no	1		
			Land use plans embedding risk mitigation and vulnerability reduction	binary; specific indications for vulenrable locations	yes/no; specific rules for the wildland-urban interface and for accessibility	1		
			If previous paramters yes, then Implementation capacity	binary; frequency of inspections; trained personnel for inspections	yes/no; every year/seldom	1		
			If previous paramters yes, then Integration to other measures (insurance)	binary	yes/no	1		
Infrastructure and production sites	*Critical infrastructures*	Existence of vulnerability assessments for critical facilities; level of consideration of vulnerability in programs regarding critical facilities	Vulnerability assessment of critical infrastructure	binary, particularly for roads and water for firefighting	yes/no	1		
			Maintenance programs embedding mitigation	binary	yes/no	1		
			New projects based on hazard/risk assessment	binary	yes/no	1		
			Level of coordination among stakeholders	degree	low/medium/high	1		
	Production sites	Existence of vulnerability assessments for production sites; consideration of na-techs	Vulnerability assessment of production sites to wildfire	binary	yes/no	1		
			Retrofitting measures for existing production sites	binary	yes/no	1		
			New projects based on risk assessment	binary	yes/no	1		
			Na-tech explicitly accounted for in hazardous installations emergency plans	binary	yes/no; expert judgement on quality	1		
Social system (agents)	*People/individuals*	Capacity of individuals living in prone hazard areas of coping with hazardous events, which largely depends on the perception and awareness of risk conditions before the event occurs.	Risk perception/ awareness	Degree	strong/average/low	0.5		
			Reliance on institutional firefighting capabilities	Degree	strong/average/low	1		
			Felt responsibility for firefighting and fire mitigation	Degree	strong/average/low	1		
			Tools and plans to guarantee early warning reach the communities	Binary	yes/no	1		
			Individual preparedness	regarding specific self protective measures; regarding measures included in emergency plans	hydrant available/not available; escaping routes known/not considered	1		
	Community and Institutions	Evaluation of the involvement of a community into decision-making processes related to risk prevention and mitigation, the capacity of Instituions of improving risk awarenees through information and education campaigns and the level of cooperation among different institutions in charge of risk prevention/ mitigation.	Contingency plans for firefighting	binary	yes/no	1		
			Effectiveness of measures included in contingency plans	degree	strong/medium/low	1		
			Participation in development and prevention/mitigation strategies	degree	strong/medium/low	0.5		
			Education programs & media campaigns	binary; frequency	yes/no; every year/only seldom	0.5		
				tailored to the community features	yes/generic	1		
				Inclusion in school programs	yes/no	1		
			Economic access to resources for firefighting	degree	vewry low/low/average/high	1		
			Coordination and cooperation among institutions in charge of risk prevention/ mitigation	degree	strong/medium/low	1		

Matrix to assess mitigation capacity to forest fires

Risk: forest fires; **Second Matrix: Physical vulnerability: Vulnerability to stress (hazard**

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters values and/or categories	weight	score (1=high; 5=very low)	Scale
Natural environment	*Natural ecosystems*	Fragility of natural ecosystems to hazard(s)	land cover inflammability	Surface fuels	Only needle or leaf litter on the ground; sparse low vegetation; tall dense phyrgana or shrubs	1		
				Existence and cover of tall tree crowns	No tree crowns; tree crown cover of <40%; tree crown cover >= 40%	0.5		
				Type of trees (see next page for details)	according to the classification provided by Dimitrakopoulos and Papaioannou, 2001	1		
		Vulnerability of ecosystems to mitigation measures taken during emergency	can natural ecosystems may be impacted by mitgiation measures?	Binary	Yes/no	0.5		
Built environment	*Exposure and vulnerability of built environment*	Factors that make buildings, the urban fabric and public facilities vulnerable to the stress	Average vulnerability at the municipal scale, considering settlements(rural) or urban parts	Considering parameters provided in the attached specific table	Low-medium-high vulnerability	1		
			Types of dangerous uses within or in proximity to the building unit of reference (either in the horizontal or vertical sense)	Flammable storage inside or close to residential areas	Absent/present	0.5		
			Morphological features of settlements	Influence of the slope of the surrounding area	Slope i <5%/ 5% <= i < 20 / Slope >= 20%	0.5		
			Historic sites (archeological) and buildings (monuments and museums) in the hazardous areas	Binary; extent and relevance	no/yes; dimension; minor/relevant/very relevant	1		
			If previous parameter YES, then Level of protection	Binary and quality	yes/no; effective/uneffective	1		
			Built pattern (follwoing Lampin-Maiillet et al., 2009)	Building density and proximity is an indicator for assessing potential sources of ignition and surface to be cleared from vegetation	very dense; dense, scattered; isolated	1		
Infrastructure and production sites	*Critical infrastructures*	Factors that make critical infrastructures vulenrable (mainly lifelines)	Vulnerability assessment of critical infrastructure	water system pressure	normal/ too low pressure for hydrants	1		
				self eater tank	available/not available	1		
			roads	interaction with fuel	large road sections in open zones/in the middle of fuel areas	1		
	Production sites	Factors that make production sites vulnerable (including na-tech potential	Vulnerability assessment of production sites	as for buildings, but including attention to storage of hazmat	structurally vulnerable/low vulenrability; large storage/no storage	1		
			Vulnerability due to dependency on lifelines	depending on the degree of dependance upon external vulnerable lifelines	self eater tank available/not available	1		
Social system (agents)	*People/individuals*	Factors that may lead to injuries and fatalities	Sparse population	ratio between population living in isolated buildings and remote settlements and total population	r <5%; r > 20%	1		
			Preparedness	self protection means	hydrants at home/lack of hydrants	1		
				self protection against smoke	availability of masks/lack of	1		
			Age; mobility impairment, other impairment	difficulties to comply with evacuation orders; difficulties in escaping	> 65; number of handicapped	1		
	Community and Instituions	Factors that may lead to large number of victims	Distance from firefighting resources	time of arrival	within 30 min; > 1 hour	1		
			Availability of trained personnel	professional training in the community	firefighters (professional+volunteers)/only professional	1		

Matrix to assess physical vulnerability to forest fires

Vulnerability parameters for individual buildings

Aspect	Parameters	Criteria for assessment	Parameters value/ categories	weight	score (1=high; 5=very low)	Application to the Ilia case study
What are the factors that make buildings and public facilities vulnerable to the stress?	Vulnerability assessment of residential buildings and public facilities	Minimum distance between the forest fuel and the house	Distance d >= 20 m; d< 20m			Post-fire case studies revealed that ~90% of home survival depended on two factors: a non-flammable roof and vegetation cleared within 10 m of home (Foote, 2006)
		Heat tolerance of the roof	Non flammable roof/flammable roof			
		Influence of the slope of the surrounding area	Slope i <5%; 5% <= i < 20; i >= 20%			
		Heat tolerance of the walls	Non burnable walls/ flammable walls			
		Heat tolerance of the shutters	Metal shutters/wood or plastic shutters			
		Number of floors	Only ground floor/2 floors/ > 2floors			

Matrix to assess physical vulnerability of built environment to forest fires

	System	Aspect	Parameters	Criteria for assessment	Descriptors	weight	Score 1 (high) - 5 (low)	Comments
Natural er	*Natural ecosystems*	Fragility of ecosystems to potential secondary effects of hazard(s)	soil deterioration	increase of erosion	<= 30 %; 30 x x < 50%; x>= 50%	1		
			landslide hazard	degree of increase of landslide potential based on survey and exprt judgement	low/medium/high	1		
Built environment	*Exposure and vulnerability of built environment*	Factors that make buildings, the urban fabric and public facilities vulnerable to losses	Existence of public facilities and resources to face the emergency	Availability of movable fire fighting equipment or of an automatic fire-fighting network (E3)	yes/no	1		
			Accessibility to vulnerable areas	Buildings density and proximity (follwoing Lampin-Maillet et al., 2009)- total perimeter to be protected	very dense; dense, scattered; isolated	1		
				Roads characteristics	Type of roads serving the various settlements			
					Plain roads/mountain roads			
				Signs in roads and streets (names, numbers, etc.)	yes/no			
				existence of public facilities in the area	yes/no			
			Accessibility to public facilities	expected travel time	t > 30 min/ t <= 30 min			
				road network to public facilities	as for accessibility to vulnerale areas			
Infrastructure and production sites	*Critical infrastructures*	Factors that make critical infrastructures stop functioning	Existance of lifelines	Availability of water for firefighting	Yes/no; in sufficient number/insufficient	1		
					Existence of a swimming pool or a water tank of more than 3 m3 in the plot	0.5		
	Production sites	Factors that may lead to halting production	Degree of dependance of production sites from lifelines	water for fighting	existence of tanks and devices for firefighting			
			Accessibility to the plant and to markets	redundancy; quality of roads; usability; expected increase in travel time	as for roads network to vulnerable areas			
			Contingency plan for na-tech	binary	yes/no			
			Business continuity plan	binary	yes/no			
Social system (agents)	*People/individuals*	Factors that may reduce coping capacity during crisis	Access to understandable information	binary	yes/no	1		
			Trust in information provisers	binary	yes/no	1		
			Tenants, landowners and neighbours have been trained in fire-fighting	binary and frequency of training	yes/no; every x months/only occasionally	1		
			Voluntary fire fighers	binary; number	yes/no; number /neighborhood	1		
			If previous yes, then Training	degree of training and means availability to volunteers	good/average/low	1		
			Presence of impaired groups (elderly, sick persons, etc.)	binary; number and accessibility to leaving areas	yes/no; numbr/neighborhood and accessibility	1		
	Community and Instituions	Factors that may hamper effective crisis management	Existance of contingency plan fro threats at stake	binary; date of last production or update	yes/no; recent/>2 years with no updating	1		
			If previous yes, Training using the contingency plan	binary; frequency of training	yes/no; every year/only occasionally	1		
			Overlapping responsiblities among agencies	degree	Low/medium/high	0.5		
			Established protocols for information sharing	binary	yes/no	0.5		
			Established protocols for use of resources to manage the crisis	degree	yes/no/partial	0.5		

Matrix to assess systemic vulnerability to forest fires

Risk: forest fires **Fourth Matrix: Resilience: response capability in the long run**

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters values and/or categories	Weight	Score 1 (high) - 5 (low)	Comments
Natural environment	*Natural ecosystems*	Ecosystems capacity to recover from damages	recovery capacity of burnt areas	extent of damage to vegetation	Resprouting likely/unlikely	1		
			Fire interval	Elapsed time between two consecutive fires (The study by Delgado etal 2002 is used as reference. They evaluated resilieance of vegetation in the Mediterranean context, using Catalonia as a case study. The type of vegetation studied should be similar for many mediterranean ecosystems. They measure plant cover recovery 38 months after the second fire).	Days	1		
			Fire recovery	Post fire vegetation re-growth	South facing slopes/North facing slopes	0.5		
				logging procedures	immediate logging after fire/delayed logging (see Spanos et al., 2010)	0.5		
			burnt areas management	plants used for reforestation	use of endemic species for reforestation/use of fast growing vegetation	1		
		Structural and non structural recovery measures	availability of maps and pictures to document regeneration	binary	yes/no	0.5		
Built environment	*Exposure and vulnerability of built environment*	Urban fabric/built environment capacity to recover reducing pre-event vulnerability	Existance of plans and provisions to encourage mitigation in buildings and surrounding zones	binary	yes/no	1		
			Creation of emergency access	binary	yes/no	1		
			Level of sharing among stakeholders of reconstruction plans	degree	low/average/high	1		
			Level of integration of physical reconstruction with community healing processes	Room is given for interpreting in the new/restored setting the meaning of the destruction (After Valen and Campanella, 2005)	High/low	0.5		
			Existence and strength of norms prohibiting building in burnt areas	binary; degree of compliance/inspection capability	yes/no; low/high			
Infrastructure and production sites	*Critical infrastructures*	Availability of tools to recover critical infrastructures rapidly and at low costs	Water system for firefighting	level of improvement after disaster	low/high	1		
			In site devices for quick survey of damaged parts	binary	yes/no	1		
			Availability of spare materials for fast repairs	binary	yes/no	1		
			Availability of personnel for repairs	binary	yes/no	1		
			Existence of protocols to proceed with repairs requiring inter-lifelines interventions	binary	yes/no	0.5		
	Economic activities	Availability of tools to recover production sites rapidly and at low costs	Relevance of the area as a tourist attraction	degree	low/average/high	1		
			Activities depending on the existence of woods	binary	yes/no	0.5		
			Economic sectors	Diversified or concentrated on few sectors	Few/many different economic sectors in the area	1		
Social system (agents)	*People/individuals*	People's resilience in the face of the catastrophe induced trauma	Availability of psychological support for adults and children	degree	yes/no/making part of ordinary practices			
			Availability of private resources for recovery	degree	yes/no			
			Availability of private resources for recovery	Income/per capita	high/average/low			
			Access to insurance	binary; coverage	yes/no; percentage of coverage			
	Community	Affected community's resilience to the consequences of a catastrophe	Age structure	Aging population; low fertility rates	indexes			
			Local condition of aged population	autonomous/not autonomous; relatively healthy/not healthy	autonomous/not autonomous; relatively healthy/not healthy			
			Employment rate	degree	high/medium/low			
			Annual population growth rate (over the last five years)	degree	high/medium/low/negative			
			Immigration index	degree	high/medium/low/negative			
			Social networking	degree	high/medium/low/negative			
			Criminality rate	degree	high/medium/low			
			Conflict among social/ethnic groups	degree	high/medium/low			
	Institutions	Transparency, reliability and trustability of institutions in charge of reconstruction	Trust in institution	degree	high/medium/low (from sociological surveys when available)			
			Transparency in funds allocation	Existance of public information and independent control mechanisms	yes/no			
			Long term vision	Existance of strategic development/land use plans	yes/no			
	Economic stakeholders	Capacity and willingness of stakeholders to reinvest in affected areas	Insurance coverage	binary; coverage	Yes/no;percentage			
			Dependance of economic actors on loss of environmental goods	Prevalent tourist acitvity; agricultural activity	percentage			

Matrix to assess resilience to forest fire