ENSURE PROJECT

Contract n° 212045

WP5:

Application of an integrated vulnerability conceptual approach

Del. 5.3.1:

Development of the Integrated Approach on the Ilia case study

Reference code: ENSURE – Del. 5.3.1

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1 General presentation of the Ilia case study

The aim of ENSURE project is to develop a new method for assessing the various aspects of Vulnerability and Resilience to several hazards and all along the disaster cycle. The main idea is to provide a comprehensive and structured tool to assess communities' vulnerability at regional and local level by analyzing the natural environment, built environment, infrastructure-production sites and social systems. This tool is going to be tested in multi-hazard areas that have suffered from severe natural hazards in the past.

The Prefecture of Ilia (NUTS III level) is one of these areas that have been selected for the application of the methodology. Ilia is located on the western part of Peloponnese, Greece and covers an area of 2.681 km^2. Hosting 193.288 inh. (2001 population census), is divided into 22 municipalities and its capital city is Pyrgos (Figure 1).

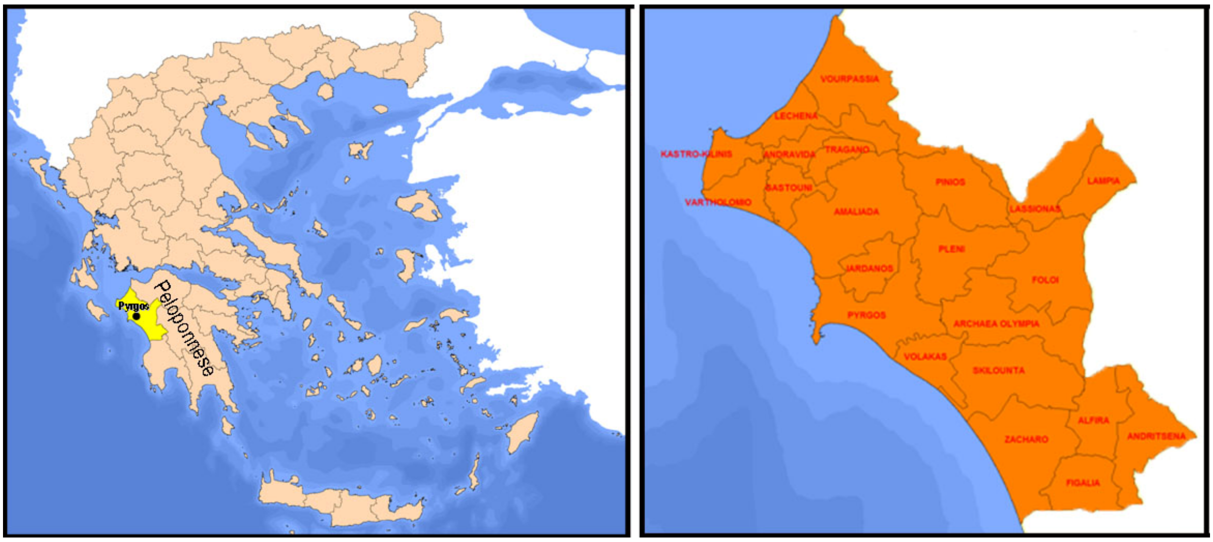

Figure 1: Ilia's location and administrative division (municipalities)

The eastern part of the peripheral unit is forested, with mostly pine trees in the south. In the north is the Strofylia forest which has pine trees. Mountain ranges include Movri (around 400 m/1,700 ft), Divri (1.500 m) and Minthi (1.100 m).

About 1/3 of the land is fertile, the rest is mountainous and not suitable for crops. Swamplands used to cover 1-1.5% of the region, especially in the Samiko area. Most of them have been drained for agricultural purposes; only 10 km^2 have been kept unaltered and are now protected. Here lies also the ancient ruins of Olympia, a well-known spot due to the ancient Olympic games which were first hosted here in 776 BC.

Ilia was chosen as a test area for the methodology due to the fact that is a multi-hazard area suffering from forest fires, floods and earthquakes. Three groups of matrices –one for each of the three hazard types– have been constructed to assess the levels of vulnerability / resilience of the ecological, built, production and social systems in Ilia. The first group deals with vulnerability versus forest fires and is spatially focused on the municipalities of Krestena, Zacharo and Arhea (Ancient) Olympia. The second one is about vulnerability versus flood hazard and refers to the Municipalities of Pyrgos, Archaea Olympia and Andritsena. The third group on vulnerability versus seismic hazard is applied to the territory of Pyrgos. In the case of forest fires, the vulnerability / resilience matrices were estimated on the basis of a specific recent event, that of the mega-fires of August 2007 (see Figure 2). On the other hand, the matrices and vulnerability scores referring to the flood and seismic hazards have been based on hazard scenarios.

Figure 2: Satellite image of Peloponnese after the August 2007 mega-fires.

(areas in red are forests, while burnt areas are marked grey – after WWF Hellas and AUTH, 2007, p.6)

Data for the Ilia case study were collected by using two methods: (a) creation of appropriate data bases and (b) interviews. Regarding the former, all data has been primarily collected through various sources (National Statistical Authority, National Geological Survey, various cartographic sources, the HUA team members' own statistics and database archive). All data have been translated into English, as there would be only a handful of data that were primarily available in English. As far as cartographic information is concerned, the HUA team had to digitize various analogue (printed) maps. Then a spatial database was created including topography, geology, landslides, road network, building blocks, land uses, ecologically protected areas, forests, gas stations, population data etc. using Geographical Information System (G.I.S.) techniques. This was based on the MapInfo software, a user-friendly and easy to use desktop mapping package with increased capabilities of thematic mapping and spatial analysis. Data procedure in the analytical context of GIS provided data integration which includes a common geographical reference system, common spatial and temporal coverage, and similar scale and quality of the data. All info ware then made commonly available through the ENSURE extranet, while it was not uncommon that the Greek team was making continuous efforts to improve data quality, as well as to make more data available at partners' requests, data which were hard to find and always in need of first-hand elaboration, a task that required at least to deal with the language and database compatibility problems.

Data have also been collected through interviews with public officials at the local and regional level, as well as with competent staff of Public Utility companies. In particular, questions were addressed to public officials working at various local municipalities, the Forest Service and the Public Power Corporation via emails, fax and telephone calls. Whenever possible, information and data have been cross-checked to test their reliability. This ad-hoc method was helpful in providing with a lot of missing data, but is has to be noted that the unfriendly research conditions regarding availability and consistency of primary data in Greece could not been easily bypassed by the efforts of the HUA team, taking into account the limited time and resources.

2 Hazards characterization

2.1 Forest fires

In Greece, about 2,5 million hectares of land (19,8% of total surface area) is tall forests, while a further 3,2 million ha are partially forested areas and shrublands. There are also about 1,9 million ha of grasslands and phrygana (mainly used for grazing) (Xanthopoulos, 2008). Forest fires, while considered an endemic feature of Mediterranean forests, began to be a problem in the 1970s, a fact that is related to socio-economic changes occurring at that time (ibid – see Figure 3). One can't escape noticing the peak of the 2007 forest fires burnt areas, the majority of which affected Peloponnese and Ilia in particular.

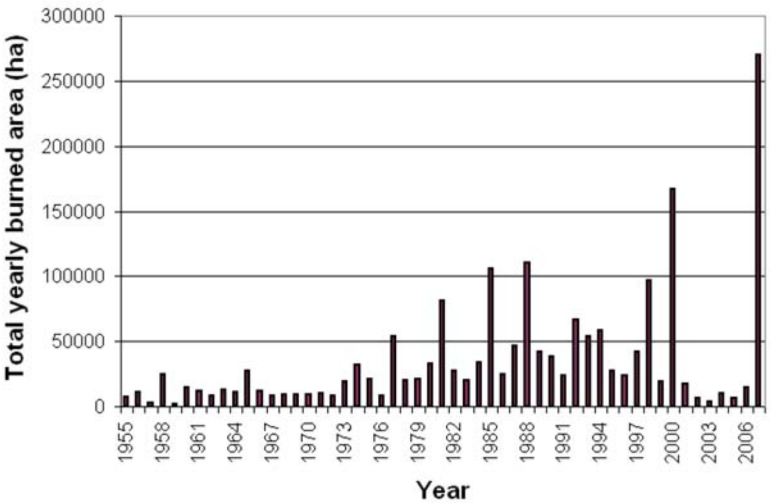

Figure 3: Evolution of total yearly burned area in Greece, 1955-2007

(after Xanthopoulos, 2008, p. 3)

According to Papountzaki and Papachatzi (2008), the forest fires that ravaged Ilia in August 2007 are reported to have caused: tens of losses of human lives; 6,000 homeless people; 168 municipal districts or 1994 km^2 declared as disaster areas –i.e. 76% of the total area of the Prefecture– and 39% of the total forest land of the Prefecture been burnt (AUA 2007); thousands of hectares of burnt natural areas of significant value and unique bio-diversity (WWF-Hellas and AUTH 2007); severe infrastructure and building damages in most of the settlements of the Prefecture; huge losses in the livestock farming sector; damages in vegetal stock covering an area that represents 14,3% of the Totally Used Agricultural Area; damages in olive-tree cultivations, as well as losses in grapevines, walnuts and almonds (AUA, 2007); disruptions and failures in basic lifelines, i.e. the road network, crossings and bridges, electric and water supply networks etc.; damages in farmers' capital (i.e. storages and sheds, mechanical equipment etc.); medium-term atmospheric pollution that spread beyond Peloponnese to the distant northern coasts of Africa; rural landscape degradation and destruction of environmental amenities and tourism resources; disruption of incomes, closure of firms and disruption of the wider socio-economic life of the local communities; and finally, long-term uncertainties and threats relevant to economic decline, demographic decay, displacement of locals etc.

2.2 Floods

In Greece floods are usually produced by intense rainfall from frontal systems and also by convectional activity. Cyclonic conditions can produce storms that persist for many hours whereas convection processes cause thunderstorms of shorter duration (Mimikou and Koutsoyiannis, 1995). Ilia is characterized by some rivers with medium sized basins and flows (50-2000 square kms) such as the Alfios basin which runs through gorge sections. These rivers have a torrential rainfall regime, major permanent river flows and some of them have ephemeral streams in some parts of catchment. These rivers are often used for impounding and storing water. Secondly, there are the short littoral water courses with steep gradients. These water courses occupy small catchments (5-50 square kilometres), are characterised by a torrential regime and have non-permanent flows: these are ephemeral rivers. Many of these rivers have steep gradients and occupy narrow V-shaped valleys with narrow floodplains.

Floods in the river systems or water courses of the Ilia region are usually characterized by high velocity, rapidly rising, high impact events which may also be deep in places, depending upon the length of rainfall and its intensity. Flash floods are characteristic. LLasat *et al.* (2010) show that for Greece flash floods are more common in the Autumn (particularly in November but also October) and in some Winter months (January in particular), and less common in some summer months (e.g. May, June and August) although floods can still occur in these months. Therefore, if there are particular agricultural or other productive processes going on in the months in which flash flood producing conditions are more common in Ilia, then these processes are likely to be impacted most.

LLasat et al, (2010, p51) state that the role of deforestation and urbanisation is very important in flood genesis in western Greece. The floods are more destructive in the western part of Greece due to the climatic, geomorphic, geomorphologic, vegetation and human conditions. Floods in ephemeral streams are particularly worsened by the loss of trees and bush from forest fires. Fire lays hill slopes bare and the rainfall and runoff absorbing and retarding qualities of vegetation are substantially reduced, thus setting up conditions which can lead to a flood disaster. Such floods are likely to contain a high and potentially damaging debris load, and a good deal of silt. In Ilia, loss of vegetation caused by forest fires has enhanced soil erosion resulting in high volumes of water-sediment mixture, resulting in lower levels of infiltration and increased runoff during rainfall. Watershed management is a key issue in managing flooding from ephemeral streams but this is often not well administered. In these kinds of conditions, muddy floods and mudflows can also occur, and flash floods will often carry a debris load which is an additional damage factor.

Flooding on ephemeral streams and rivers is most commonly found where stream/river catchments are small. The speed of response (i.e. the lag time) of a river to rainfall shortens as drainage basins become smaller (Figure 4) making the floods more dangerous. As Creutin *et al.*, (2009) point out, the more we move to smaller scales the more vulnerable people and settlements are to flash flooding. Firstly, at small scales people are exposed and vulnerable to flood hazard individually, or in small groups or in a diffused manner in space (Drobot and Parker, 2007). Secondly, the more we move to these smaller scales – typical of small rural ephemeral stream catchments in Ilia – the less likely people are to be protected by traditional structural flood defences which are too expensive to build in these locations (Figure 5).

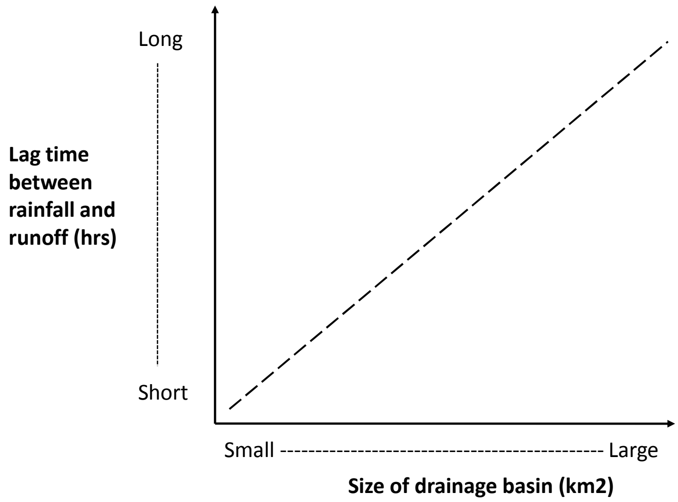

Figure 4: Relationship between rainfall-runoff lag time and size of drainage basin

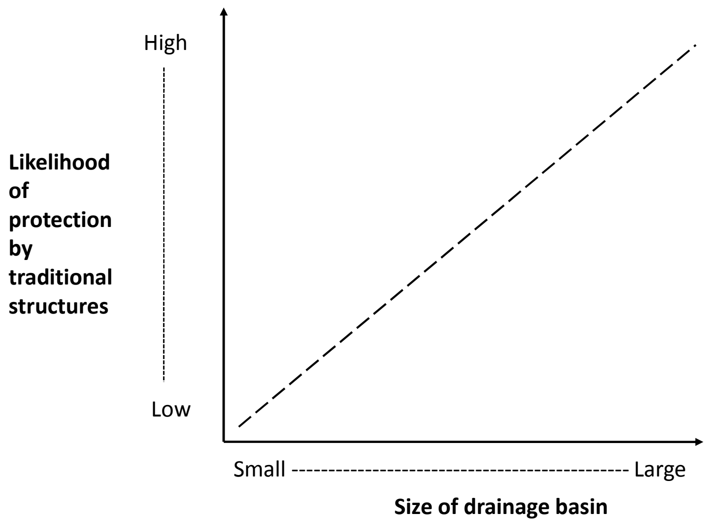

Figure 5: Relationship between likelihood of protection by traditional structures and size of drainage basin

It is likely that only a relatively small proportion of the total land area of the Ilia prefecture is directly at risk from fluvial flash floods (i.e. perhaps less than 10%), although the risk is likely to occur along many river and stream valleys and deltas as, upland floodplains are narrow. River and stream gradients are steep leading to fluvial deltas at the coast and silt, mud and other material transports downstream. The impacts of these ‘flashy’ floods, with their short ‘lag’ times, depend upon the type of event and flood generated. In short-lived events damage is usually limited but floods can bring road traffic to a standstill, produce power cuts and sweep cars away; loss of life is usually the result of trying to cross a water course. Longer flood events potentially produce the highest number of casualties when they affect villages or towns and some may produce partial or total destruction of infrastructure and lifelines (bridges, roads, sewers, water and electricity supply lines, telecommunications), houses and agricultural and livestock losses; these floods can also frequently result in loss of life. The risk to life is heightened by the flashy nature of floods in Ilia and also by the fact that many stream beds are dry during some months of the year making them appear to be non-threatening.

2.3 Seismic hazards

Structural and seismotectonic background

Western Peloponnese is among the most seismically prone areas of Southern Europe. The study area is situated where orthogonal convergence between the African and the European plate is occurring. The subducting plate is gently sloping under the Peloponnese and steepens abruptly under the Corinthos area. Two subduction-related seismotectonic regimes were recognized (Koukouvelas *et al.*, 1996): (1) a trenchward compressional regime incorporating the Ionian Islands and (2) an extensional back-arc regime including central mainland Greece, the Aegean islands and the Peloponnese. Extension within the back-arc area is accommodated mainly by WNW-trending seismogenic normal faults, typically from 10 to 15 km in length (Figure 6).

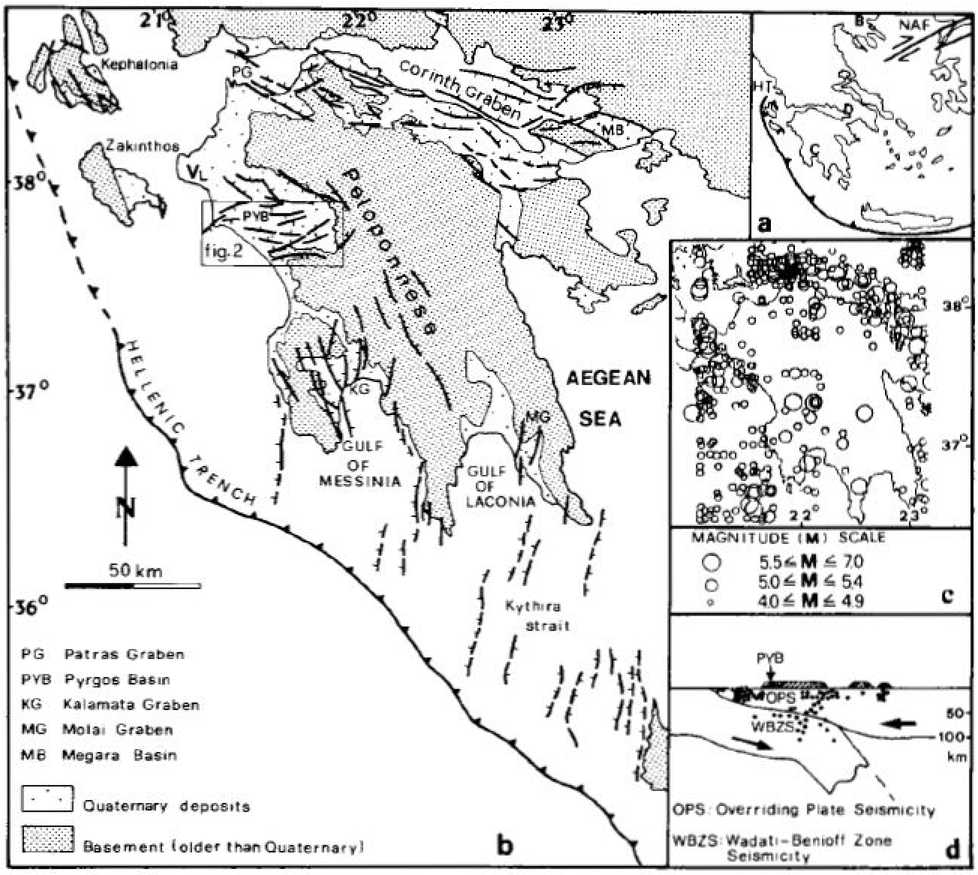

Figure 6: (a) Map showing the position of the study area in relation to the Aegean province. (b) General tectonic setting of Peloponnese with outline of Quaternary tectonics, Pyrgos Basin in rectangle. (c) Seismicity map of Peloponnese. (d) Cross-section.

(From Koukouvelas et al.*, 1996).*

Historical Seismicity

According to the reports of historical earthquakes with origin in the Ilia area, seismic activity is relatively high. For the last Century, twenty four earthquakes, with magnitude 5.5 to 6.6, have occurred (Table 1 and Figure 7).

Year	Month	Day	Latitude	Longitude	Depth	Magnitude
1925	JUL	6	37,8	22,1	80	6,6
1939	SEP	20	38,0	21,0	60	6,3
1953	AUG	12	38,0	21,0	10	6,3
1965	APR	5	37,8	22,0	10	6,1
1988	OCT	16	37,9	21,0	4	6,0
1909	JUL	15	37,9	21,5	0	5,7
1926	FEB	26	37,8	21,1	0	5,7
1954	DEC	23	37,9	21,1	10	5,7
1910	DEC	27	37,9	21,2	0	5,6
1914	SEP	17	37,7	21,0	0	5,6
1915	MAY	17	38,0	21,0	0	5,6
1926	FEB	26	37,8	21,1	0	5,6
1955	MAR	28	37,7	21,2	10	5,6
1973	JUL	14	37,8	21,2	5	5,6
1999	JUN	11	37,6	21,1	55	5,6
1903	MAR	15	37,8	21,2	0	5,5
1953	AUG	12	38,0	21,0	10	5,5
1954	JAN	18	37,8	21,3	10	5,5
1954	JUL	18	37,5	21,5	10	5,5
1983	SEP	8	37,6	21,0	5	5,5
1987	MAY	29	37,5	21,6	29	5,5
1988	SEP	22	38,0	21,1	5	5,5
1993	MAR	26	37,7	21,4	5	5,5
2002	DEC	2	37,83	21,12	17	5,5

Table 1: Historical earthquakes in the area of Ilia for the period 1900-2010

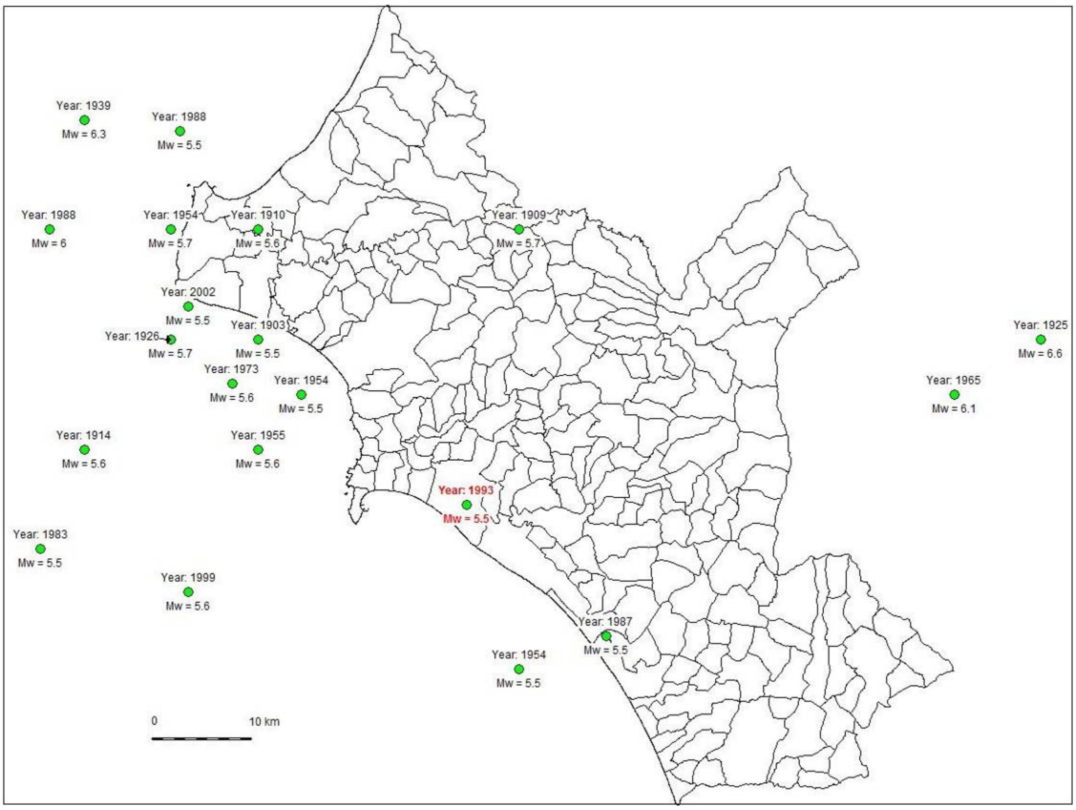

Figure 7: Distribution of epicenters close to Ilia Prefecture: in red the earthquake used for seismic hazard in the Ensure Project

Recent Seismicity

Instrumental data confirm a relatively high seismic activity (Figure 8). Most of earthquakes are shallow, less than 40 km depth. The typical magnitude of the onshore seismicity in the Peloponnese is around M_w = 5.5.

During the last twenty five years, four moderate to severe earthquakes have taken place in Western Peloponnese causing loss of human lives and severe damage to buildings, as well as to ports and other public facilities. More specifically, on March 26, 1993, an earthquake of a magnitude M_S *5.5* shook the town of Pyrgos.

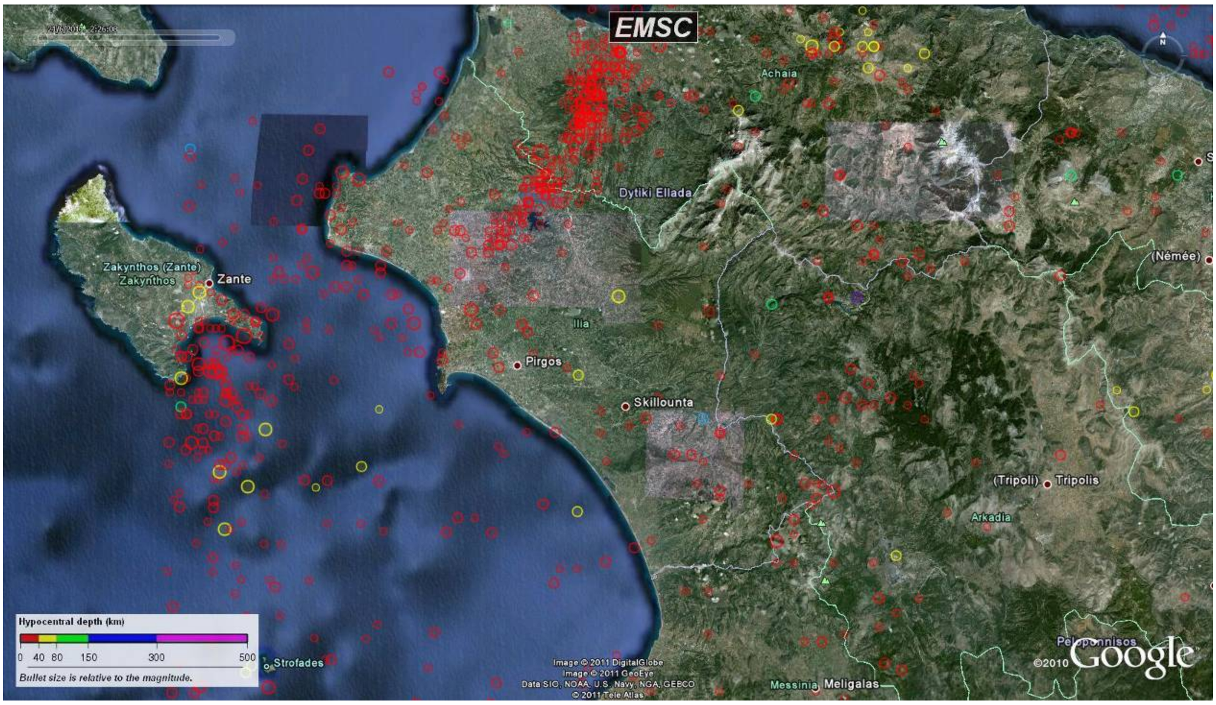

Figure 8: Distribution of earthquake epicenters with Mw > 3 around Ilia from 2005 to 2011 (data from European-Mediterranean Seismological Centre)

Earthquake scenarios

To assess seismic hazard on Ilia Prefecture, two scenarios of seismic motions were retained:

1) The first scenario is similar to the 1993 earthquake, with a magnitude M_w = 5.5, and a focal depth of 17 km (Figure 7). In 1993, two people were slightly injured and damages were reported in the Pyrgos-Amalias area. This earthquake was felt in Akhaia, Arkadhia, Ilia, Messinia and Zakinthos Prefectures. We chose this earthquake because his close location to the Pyrgos town and of his shallow depth; the others earthquakes are too far from Pyrgos or too deep. To estimate earthquake peak ground acceleration (PGA), we used the empirical ground-motion prediction equations of Sadigh *et al.* (1997).
2) The second scenario is the local Peak Ground Acceleration (PGA) from the Greek building code (Tselentis & Danciu, 2010), 0.33 g for Ilia Prefecture (Figure 9).

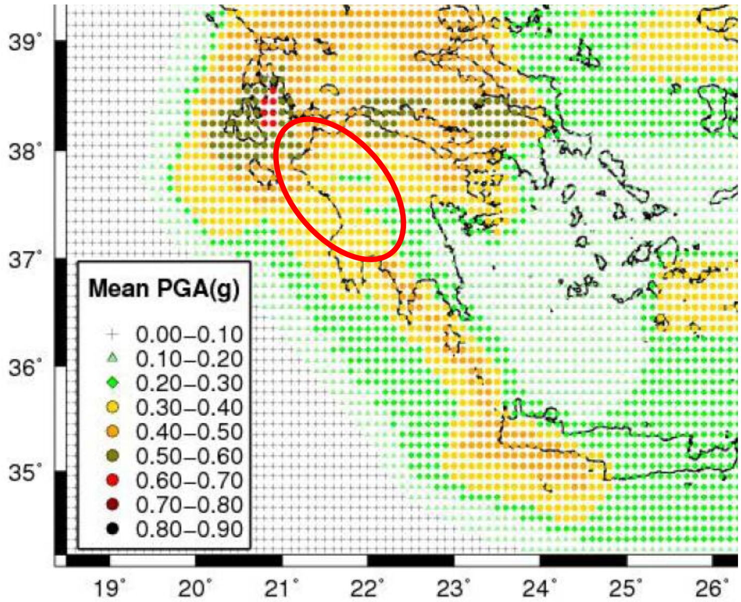

Figure 9: Extract of the probabilistic seismic hazard map for Peak Ground Acceleration (PGA) according to the Greek seismic code. The value of 0.33 g used for Ensure Project in Ilia area (from Tselentis & Danciu, 2010)

Site effects

The significance of ground-shaking during an earthquake depends on the magnitude, the distance from the fault and the local geological conditions. The most intense shaking experienced during earthquakes generally occurs near the rupturing fault, and decreases with distance away from the fault. In a single earthquake, however, the shaking at one given site can easily be 10 times stronger than the one produced at another site, even when their distance from the ruptured fault is the same. Local geologic conditions are the cause of this difference in shaking intensity known as "site effects".

The most critical geological factors defining the seismic response at a site are: the softness of the rock or soil near the surface (shaking is amplified in softer soils) and the thickness of the sediments above hard bedrock (shaking is amplified when soil deposits are thicker).

To take into account site effects in Ilia area, we identified, from the geological map of Ilia area (Figure 10), the soil types who can potentially amplify ground shaking. For each soil type, we assign through expert advice, an amplification factor of Peak Ground Acceleration (PGA) increasing with soil softness:

- factor 1.8: alluvial and coastal deposits, … ;
- factor 1.4: clays, conglomerates, …. ;
- factor 1: other soils and rock.

Finally, we produced a site effects map relative to amplification factors (Figure 11).

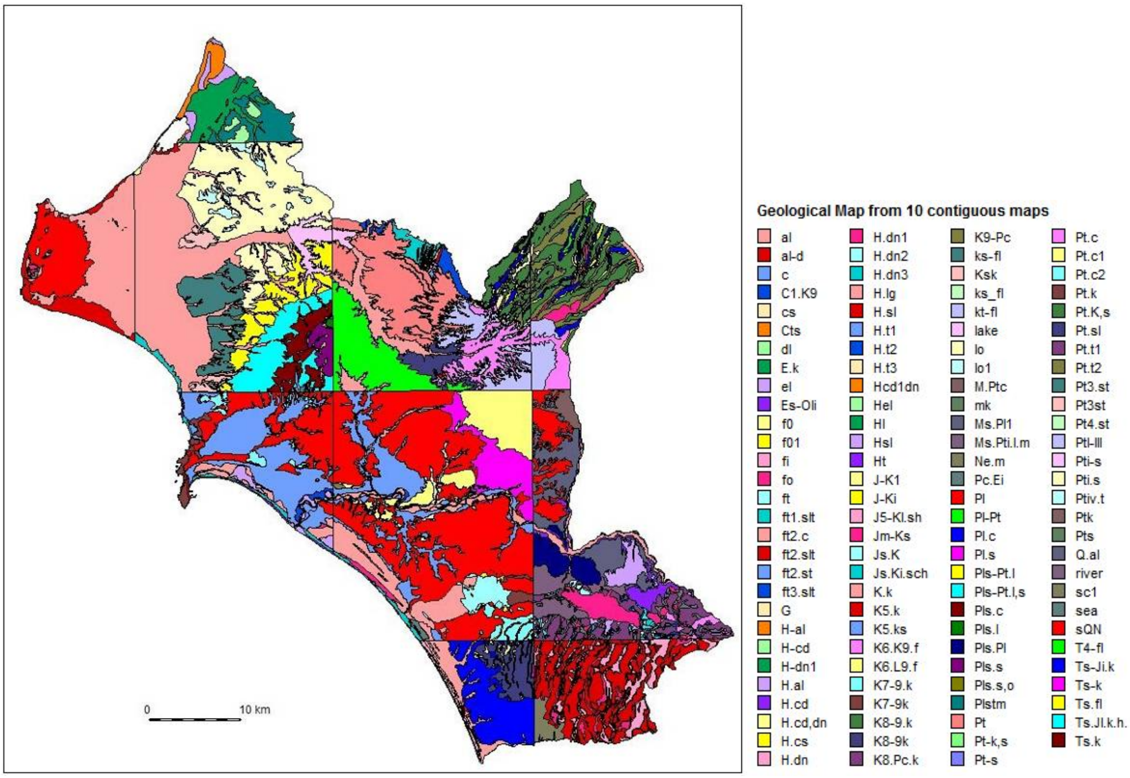

Figure 10: Geological Map of Ilia prefecture resulting from 10 contiguous maps at scale 1:50000 (Institute of Geology and Mineral Exploration): Amalias (Year 1979), Goumeron (Year 1981), Olympia (Year 1972), Pyrgos (Year 1980), Vartholomio (Year 1969), Kato Fighalia (Year 1973), Kiparissia (Year 1979), Nea Manolas (Year 1977), Kertezi (Year 1979), Tropaea (Year 2008)

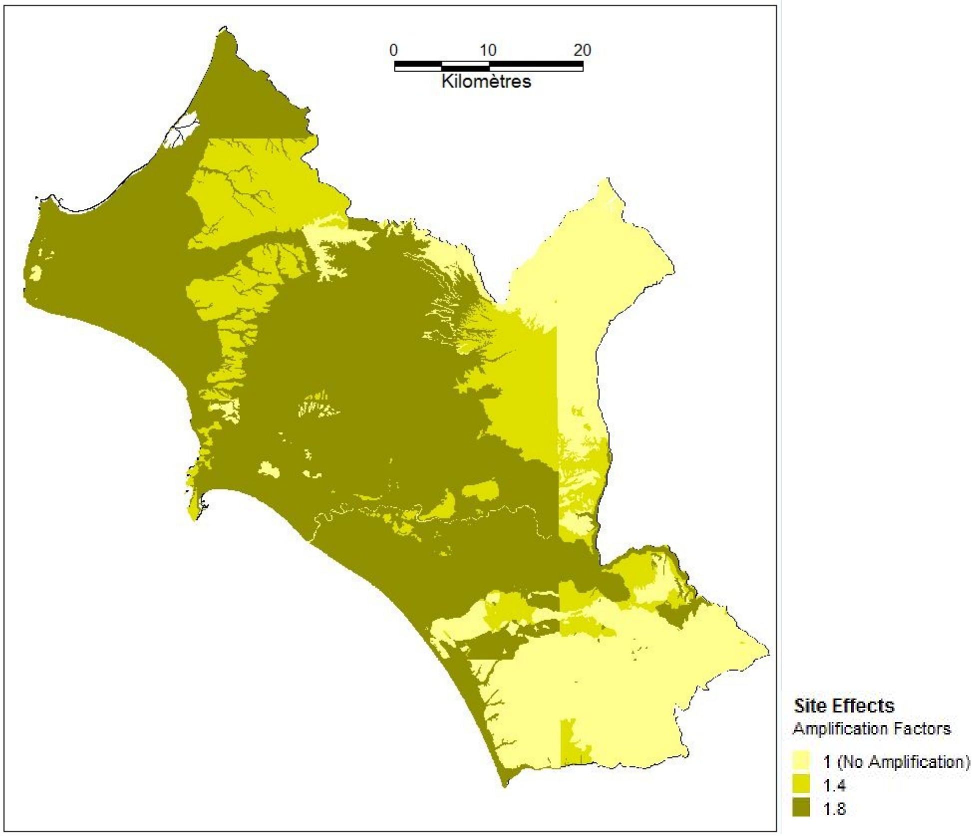

Figure 11: Site effects map of Ilia area

Seismic hazard maps

The proposed seismic hazard maps of Ilia (Figure 12) are the result both of the propagation of seismic waves from the source to the whole area and the local amplification by site effects. This assessment is issued from the BRGM software of seismic risk assessment (*Armagedom@*).

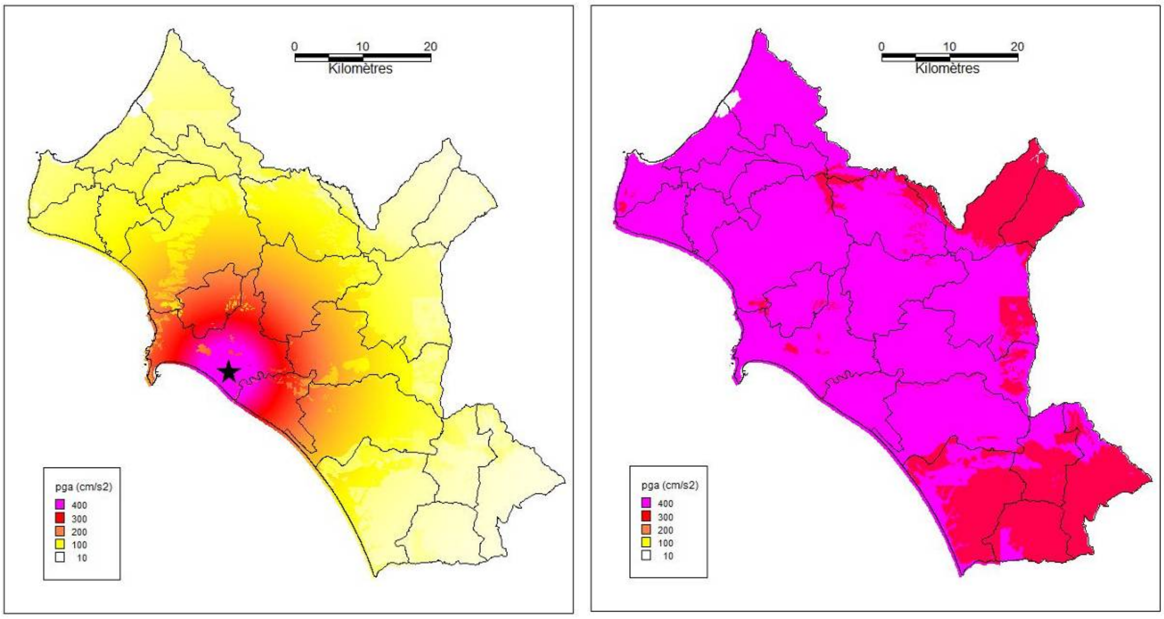

Figure 12: Seismic hazard maps for Ilia area: Left with the earthquake scenario of M_w=5.5 and Right with the Peak Ground Acceleration (PGA) from Greek building code

3 Socio-economic settings of the case study

Ilia's GDP per capita has increased by 8,1% in the decade 1995-2004 vis-à-vis an increase of 11,5% at the national level. As a result, while Ilia's GDP per capita corresponded to 66,7% of the national average in 1995, it fell behind in 2004, representing only 53% of the national average (census data, 2001). According to the description of the social and demographic profile of the Prefecture by Sapountzaki and Papachatzi (2008):

> "In proportional terms the Prefecture as a whole retains population of productive ages (i.e. 15-64) constant but loses population of young ages (i.e. up to 14 years). Numbers of marriages and births decrease in Ilia and so do birth and fertility rates causing changes in population composition and population ageing. Certain researchers ascribe the zero natural population growth and the reduction of births to local unemployment, low salaries, lack of state welfare provisions to family and children and other socio-economic reasons. Indeed the rate of employment in the primary sector is 35,1% a percentage that is more than double the respective national average (14%) and unemployment has been higher than that of the national level. Some illiteracy and the generally low education level of the population add up to the social and economic vulnerabilities of the human capital of Ilia".

The communities of the Prefecture epitomize everything that can render a social and economic system vulnerable to threats and disasters in the sense of lack of capability to withstand impacts and losses and to cure them rapidly and effectively:

- Its low GDP signifies an economic system without reserves and pools of resources to appeal to in a crisis situation (lack of redundancy and resourcefulness).
- Population ageing entails limited capability for innovation (towards resilience), for learning capacity, for robustness; besides due to bodily weakness aged groups present problems of self-reliance.
- The almost unilateral development of the primary sector means lack of diversity, flexibility and redundancy. In addition, in the period 2000-2004, agricultural output increased only by 0,4% (while change at the national level has been 1,1%), a fact that indicates loss of competitiveness.
- Unemployment and the low education level, implies lack of necessary resources for recovery, limited learning capacity, capacity for innovation, adaptability and self-organization as well as dependency on public welfare services.

One should add to the vulnerabilities of Ilia its institutional system's vulnerability owing to the inert and lack of drive for intervention on the part of the Local Development Companies as well as economic dependence of the Prefectural and Municipal Authorities on Central Government.

The ecological system of Ilia has also been vulnerable, as well as the natural assets and amenities and local cultural heritage. At a distance of 20 km east to Pyrgos (the Prefecture's capital city) and on a site within a valley between the Cronius Hill, the river Alfios and its tributary Kladeos lies the ancient Olympia, one of the most important archaeological sites of Greece and internationally, too. The monuments and their marvelous delicate setting have been protected by the Natura 2000 regime until this was breached by the flames of August 2007.

Sapountzaki and Papachatzi (2008) present in detail the vulnerabilities and exposures of the ecological system:

"... over-exploitation and waste of surface and underground water reserves, intensive agriculture and use of fertilizers, expansionary land uses and land use conflicts, plenty of scattered, illegal dump sites adjacent to forest vegetation and cultivated land, illegal and semi-illegal out-of-plan building developments, careless and harmful farming practices (e.g. burning crop remnants, woodcutting, trespassing, clearance works etc), droughts, floods and landslides."

Figure 13: Employment in main economic activities in the Ilia 2007 forest fires study area

What makes the overall eco-human system extremely vulnerable is dependency of the social / economic system on the ecological and vice versa. Economic and social viability of the communities in Ilia depend on vigor and in any case satisfactory condition of forest and rural ecosystems due to the exclusively agricultural and tourist orientation of local economies (Figure 13). The other way around protection of the ecosystems from the various threats (drought, fires, clearances, land use changes, frost etc) depend on human action and institutional measures.

4 Application of the Ensure framework

4.1 Introduction to the application of the framework

4.1.1 Forest fires

Assessment of vulnerability in the case of forest fires is based on a past event, the one of 2007 mega-fires, as has already been stated in the introductory section. The study area includes the municipalities of Arhea (Ancient) Olympia, Skilounta and Zaharo (Figure 14) and has been selected for its centrality in the evolution of the event. Methodology has also been already described in the general presentation section.

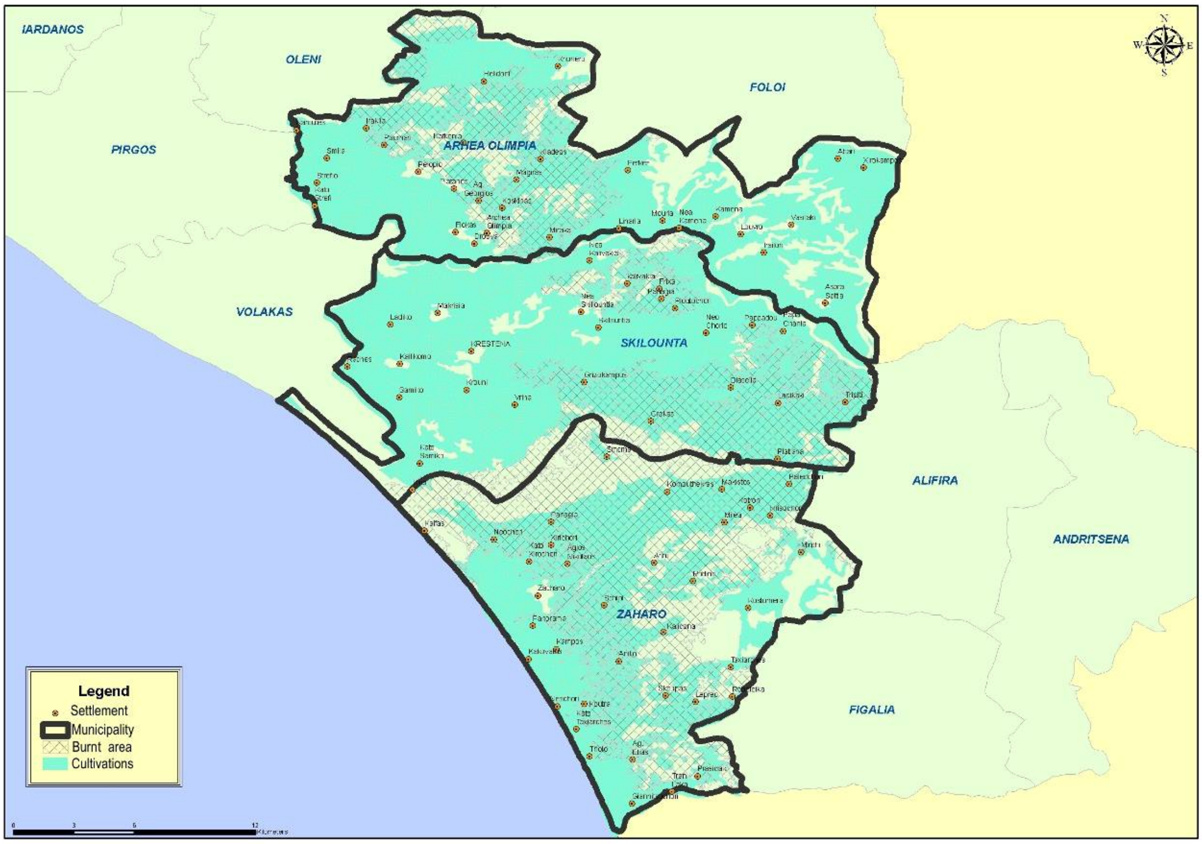

Figure 14: The Ilia forest fires study area – cultivation and burnt areas in summer 2007

In dealing with the four matrices, the initial framework has been reworked –in cooperation with other partners– in order to be operationally adjusted to data in hand. This task proved to be a demanding one, but at the end the result is quite satisfactory, since parameters and criteria for assessment reflect the particularities of the actual situation, at least to the maximum extent possible. To these criteria we have attributed specific descriptors which again needed to be reworked. Each criteria was given a weight value (either 1 or 0,5), reflecting our subjective judgement of the importance that each one may have in the overall assessment, as well as in relation to one another.

Then, given the methodology at hand, a vulnerability score was attributed to each criteria and descriptor. The pros and cons of this methodological step is analysed in the concluding section of the report. Let us highlight for now that, contrary to the judgemental nature of scoring, we have also included an “application to the Ilia case study” column on the right, in order to provide with some room for explaining the results of each matrix.

In the sections that follow we present the vulnerability matrices and also make some descriptive comments. The four matrices refer to mitigation capacity, physical vulnerability, systemic vulnerability and resilience, and each one incorporates the principal system categories of the natural environment, built environment, infrastructures & production sites and social system.

4.1.2 Floods

The application of the vulnerability matrices to the flood hazard in the province of Ilia focuses upon the Alfios river basin region of Ilia which contains the municipality of Archea Olympia and six further municipalities identified in Figure 15. In theory there are five or six different types of flooding (e.g. tidal, pluvial, fluvial, groundwater etc.) but the case study application focuses only upon fluvial and pluvial events which are characteristic of Ilia. Although other parts of Greece have experienced severe flood events in recent years, Ilia appears to have experienced few recent severe floods and so the application has been undertaken during a period when generally the flood risk is not perceived to be very great there, although this perception may well be ‘corrected’ by experience in the future.

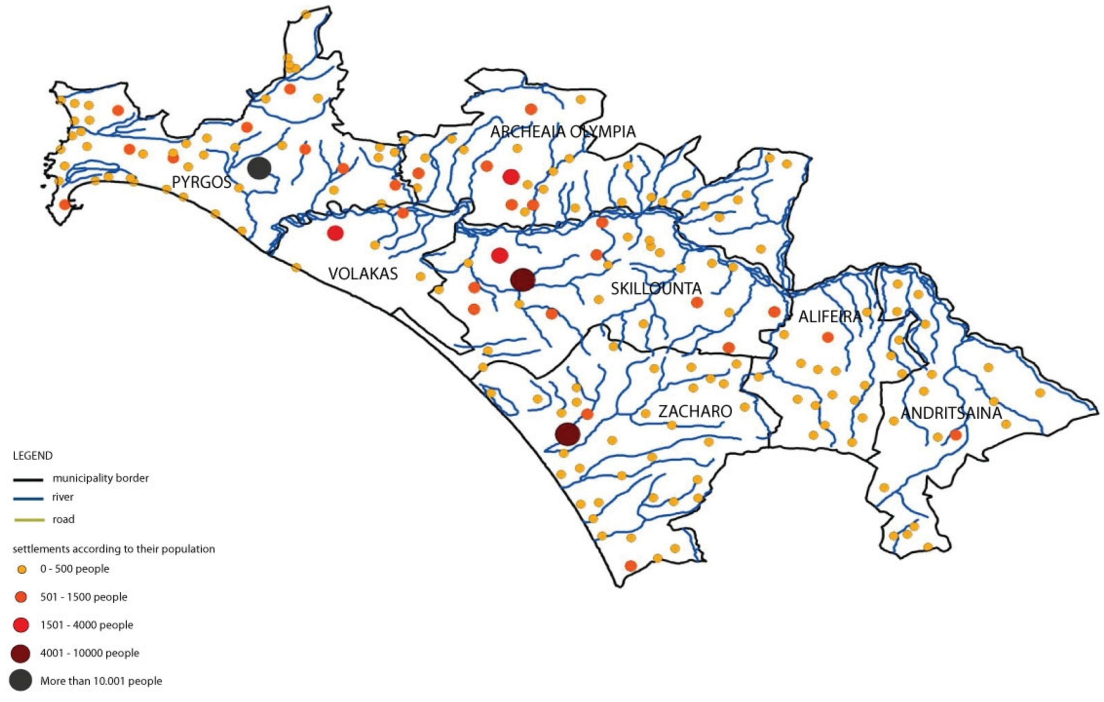

Figure 15: The flood hazard case study area showing municipal boundaries, major settlements by size and major rivers

The main issues associated with the application of the four matrices to the real case of flood hazards in Ilia concern a) depth of analysis, the acquisition and retrieval of relevant data and related data quality b) the weighting of parameters and c) the scoring of vulnerability.

It is feasible to undertake a generalised, 'broad brush', impressionistic assessment based upon readily available data. Alternatively, it is possible to undertake a deeper, more penetrating analysis and assessment based upon a wider and deeper search for and retrieval of relevant data. Indeed, it is possible to treat the application of the matrices as a piece of research in which primary data are obtained, in some cases for example, in the form of social survey results. It is also feasible to undertake an assessment at some kind of intermediate position between these polarities. Given this, data quality (which also implies data availability) is critically important and this is therefore scored in the case study application to provide an indication of the level of reliance which may be placed on each parameter vulnerability score. In this case the application to flood hazard in Ilia is performed at an intermediate level which we believe, on average, represents a deeper assessment than a generalised, broad brush, impressionistic one, but one which nevertheless still has very significant data gaps and data shortcomings indicated by the data quality scores which have been assigned. We have scored data quality from 1 = high to 5 = low.

Another issue concerns the selection of aspects and parameters. The matrices went through numerous stages of drafting and improvement reflecting a process of searching for the most appropriate and meaningful parameters in particular and also the most appropriate criteria for assessing them.

Parameters are weighted in the following way: 1 means that the parameter is considered by us to be of primary importance; whereas 0.5 means that the parameter is considered to be of secondary importance. Selection of weighting is judgemental and currently we find that it may prove difficult to apply these weightings consistently between those making assessments. A more sophisticated approach may well be required in further applications including through definition of what constitutes primary and secondary importance.

Vulnerability is scored from 1 to 5 where 1 is high vulnerability and 5 represents low vulnerability. Again scoring is judgemental and may vary between those making assessments, although our experience was that there was a relatively high level of consistency in score selections by different assessors in our case (but this may not always be the case).

The following discusses the application of each of the four vulnerability matrices (i.e. mitigation capacity, physical vulnerability, systemic vulnerability and resilience) according to the principal system divisions (e.g. natural environment, built environment etc.). Each matrix is set out from left to right in terms of systems, aspects of systems, parameters, criteria for parameter assessment, descriptors, parameter weights, data reliability and finally vulnerability scores.

Data sources for the assessment comprised web-based sources, including Google Earth census data, recent reports of the World Meteorological Organisation relating to the Hellenic meteorological service and flood forecasting and warning; and local data and knowledge provided by our Greek partners. In many cases data were missing and of inadequate quality and this is reflected in the scores in the data quality column of the matrix (and other matrices). Of course, the assessments may be further enhanced in quality by spending more resources on data acquisition.

4.1.3 Seismic hazards

The major difficulty when passing from the theoretical matrices to an application on a real case is the quantification of the different notions involved in the methodological framework describing the general vulnerability assessment. These notions are organized in different systems, themselves divided into components (also called « aspects » in ENSURE framework terminology) that are similarly split up into parameters or indicators. This quantification necessarily needs the setting up of a scoring and weighting scheme.

We decided to weight between 0 (not significant) and 1 (very significant) the four exposed systems (natural environment, built environment, production sites, social system). This weight represents the significance of one system relatively to the other with regards to the vulnerability to seismic hazard. In the case of the seismic hazard, we consider that the built environment, infrastructure and production sites are in some ways more important than the social agents, and most of all than the natural environment. Subsequently, a similar weight is applied to the aspects and the same rule is applied to the parameters that have to be ranked with respect to all the parameters found within a same aspect. For one specific parameter, multiplying its weight by the weight of the associated aspect and system leads to a general weight that gives insights on the significance of one parameter comparing to another one, no matter what the aspects or systems associated.

As far as the scoring is concerned, the criteria of assessment for one parameter can be binary, quantitative or qualitative. Concerning the parameters whose descriptor is binary, the scoring is, by definition, 0 or 1. It mostly concerns the existence or the availability of a given parameter. Concerning the parameters whose descriptor is quantitative or qualitative, a value (vulnerability score) has to be given to this descriptor, with the same scale for all parameters: in our case ranking from 0 (lowest vulnerability) to 1 (highest vulnerability). However, the quality of the data used to evaluate the parameter is of first importance and has to be taken into consideration. A data quality coefficient is then introduced in order to decrease the score if data are not good, in order to account for uncertainties. This coefficient is, in our assessment, set to 1 (good quality), 1.25 (average quality) or 1.5 (poor quality), and is then multiplied by the initial score to obtain the corrected score.

The final score is obtained for each parameter, multiplying the corrected score by the total weight. This final scoring computation leads to the ranking of all the parameters, allowing an integrated vulnerability assessment. This way of weighting and scoring permits the scoring of aspects and even systems and their ranking according to the associated vulnerability. We expect this ranking within a given exposed system to be useful in highlighting vulnerable aspects that might be ignored otherwise.

It is worth mentioning that this rather rough scoring and weighting system is a first approach and was set-up in order to check the applicability of the framework. A more sophisticated approach may need to be developed in further applications.

In the general framework presented in Work-Package 4, the physical and systemic vulnerability are studied separately through two different matrices. In order to be able to compare the indicators belonging to each of them, we merged the two matrices in one and added the time period at which the indicator is relevant. Similarly, as indicators can be evaluated at different space scales and since this information is of first importance, we added columns related to it in the matrix (see Table 2). Our analysis is presented in the physical vulnerability section that follows.

															Time		Space		
	System	System weight	Aspect	Aspect weight	Parameters	Param weight	Criteria for assessment	Descriptors	Data availa.	Data qual.	Descri. score	Param score	Aspect score	System score	I	E	Micro	Meso	Macro
Natural environment	*Natural ecosystems*	*0,2*	Are natural ecosystems fragile to the potential effects of hazard?	*1*	extent and location of triggered landslides	*1*	degree and relevance of impacted zones	extended areas / few zones	*N*		*1*				**1**				
					extent of potentially flooded zones by tsunami	*1*	degree and relevance of impacted zones	extended areas / few zones	*N*		*1*				**1**				
			Are natural ecosystems fragile to the potential secondary effects of hazard(s)?	*0,75*	areas affected by landslides	*1*	number and extent	few/many; in remote areas/in crucial-central zones	*N*		*1*					**1**			

Table 2: Extract of the modified framework for the application to seismic hazards (physical and systemic vulnerability)

4.2 Mitigation capacity

4.2.1 Forest fires

The **natural environment** in the study area of Arhea Olympia, Skilounta and Zaharo municipalities generally displays a high level of vulnerability. Table 3 shows that maps of vegetation's inflammability and of areas prone to fire do exist, but mitigation methods like integrated detection systems and monitoring staff are inadequate. On the other hand, vulnerability score is lowered due to the existence of (a) a primary technical detection system (though the functionality of which remains in question from various agents) and (b) of defences for breaking the fire lines.

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

Table 3: Mitigation capacity in Ilia 2007 forest fires – the natural environment system

In contrast to the natural system, the **built environment** is characterized by a higher vulnerability score (see Table 4). This is because aspects like consideration of exposure and vulnerability in plans or availability of mitigation rules are not prioritized by agents in charge. In particular, there is no risk mitigation planning and assessments, while hazard knowledge is not incorporated in both building rules/practices and land use plans. This is despite the fact that home ownership is extremely high or that precautionary measures are being taken at the level of the household.

The same applies to the case of **infrastructures and production sites** (Table 5). There is no vulnerability and risk assessment nor mitigation programmes, and in practice vulnerability is somehow lowered by the medium to high level coordination (both formal and ad-hoc) among lifelines providers at local and regional levels. The important aspect of the vulnerability of production sites as far as na-techs are concerned does not apply to the case of Ilia forest fires, simply because the main production activities are agriculture and small-scale tourism.

	System	Aspect	Parameters	Criteria for assessment	Descriptors	weight	score (1=high; 5=low)	Application to Ilia case study
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; updating frequency	yes/no; every time new building permits are given/only occasionally	1	1	NO
			Risk maps and scenarios, including enchained events	binary; year of production	yes/no	1	1	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	1	1	NO
	Rules and tools for risk mitigation	Do rules for mitigation exist? What is their expected efficacy/quality?	Building codes/rules	binary; updated	yes/no; rules efficacy checked after each event/rarely tested	0,5	1	NO
			Property regime of houses	owned houses versus tenants	owners ow < 50%/ ow > 80%	0,5	4	> 80%
			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	1	NO
			Maintenance of fire suppression devices and clearing vegetation around houses	binary	yes/no	1	4	YES
			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	1	NO
			If previous parameters yes, then implementation capacity	binary; frequency of inspections; trained personnel for inspections	yes/no; every year/seldom	1	-	-
			If previous parameters yes, then integration to other measures (insurance)	binary	yes/no	1	-	No but for special locations like Archaea Olympia which is a UNESCO site there were much more measures for fighting the fire (like an automatic fire detection system)

Table 4: Mitigation capacity in Ilia 2007 forest fires – the built environment system

	System	Aspect	Parameters	Criteria for assessment	Descriptors	weight	score (1=high; 5=low)	Application to Ilia case study
Infrastructure and production sites	*Critical infrastructures*	Is vulnerability of critical infrastructures assessed and acted upon? Particularly with resepct to na-techs and enchained effects on depending systems?	Vulnerability assessment of critical infrastructure	binary, particularly for roads and water for firefighting	yes/no	1	1	NO
			Maintenance programs embedding mitigation	binary	yes/no	1	1	NO data in general (but roads constructed by forest Service serve as a mitigation measure)
			New projects based on hazard/risk assessment	binary	yes/no	1	1	NO
			Level of coordination among stakeholders	degree	low/medium/high	1	4	Medium to high level of coordination among lifelines providers, there is a plan for their protection
	Production sites	Is the vulnerability of production sites considered particularly with respect to potential na-techs?	Vuln. assessment of prod. sites to wildfire	binary	yes/no	1	-	Not relevant for the area of study; mainly tourist activities and agriculture
			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	-	

Table 5: Mitigation capacity in Ilia 2007 forest fires – infrastructures and production sites

In terms of mitigation capacity of the **social system** (Table 6), vulnerability is slightly lower, compared with the one of the previous three systems. Again, specific parameters like risk awareness, responsibility vis-à-vis the hazard, effectiveness of measures and institutional cooperation are scored 2 or 1 (high vulnerability). But there is some sort of individual preparedness as long as small scale mitigation resources are available; fire fighters do implement contingency plans; and inhabitants are informed via media campaigns (though more targeted informational and educational actions are still to be promoted).

	System	Aspect	Parameters	Criteria for assessment	Descriptors	weight	score (1=high; 5=low)	Application to Ilia case study
Social system (agents)	People/individuals	Parameters are addressed to evaluate the 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	2	Average
			Reliance on institutional firefighting capabilities	Degree	strong/average/low	1	2	Strong reliance
			Felt responsibility for firefighting and fire mitigation	Degree	strong/average/low	1	2	Some volunteers are available in every settlement (though not well trained)
			Tools and plans to guarantee early warning reach the communities	Binary	yes/no	1	1	No tools and plans available
			Individual preparedness	regarding specific self protective measures; regarding measures included in emergency plans	hydrant available/not available; escaping routes known/not considered	1	4	Hydrants are available; regarding escaping routes it should be underlined that their use must be considered in connection to early warning systems which are not present
	Community and Institutions	Parameters are addressed to evaluate 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	5	Fire fighters do have a contingency plan
			Effectiveness of measures included in contingency plans	degree	strong/medium/low	1	1	Zones identified as fire breaking lines did not match plans laid out by the Fire Brigades and the Fire Service
			Participation in development and prevention/mitigation strategies	degree	strong/medium/low	0,5	2	Low participation
			Education programs & media campaigns	binary; frequency	yes/no; every year/only seldom	0,5	3	YES every summer in the TV; specific leaflets prepared by some municipalities but it is not known whether or not those reached the population
				tailored to the community features	yes/generic	1	1	Material prepared for the municipalities can be further tailored, according to local particularities
				Inclusion in school programs	yes/no	1	1	Not yet
			Economic access to resources for firefighting	degree	very low/low/ average/high	1	3	NO (not before the 2007 fire)
			Coordination and cooperation among institutions in charge of risk prevention/ mitigation	degree	strong/medium/low	1	2	LOW. Low level of consensus between the Forest Service and the Fire Brigades regarding the development of forest roads

Table 6: Mitigation capacity in Ilia 2007 forest fires – the social system

4.2.2 Floods

Mitigation capacity concerns the existing situation regarding flood hazard mitigation in the Ilia case study area. Overall, current mitigation capacity is very low and accordingly vulnerability is high. However, one issue which requires identification and further consideration concerns whether or not the number (i.e. scale) of buildings and people exposed to flood risk is a factor which should influence the vulnerability score. In this case study region, the population is rather low (circa 200,000 in Ilia as a whole), population density is low and the proportion of both buildings and people who are directly at risk from flooding is low. On the other hand, as the assessment below demonstrates, vulnerability is high. In this assessment we have elected to reflect this high vulnerability in the vulnerability scores rather than to reduce them in any way because the number of buildings/people at risk is low, but an alternative approach – not taken here - is to reduce the vulnerability scores to take into account the low proportion of buildings and people at risk.

	System	Aspect	Parameters	Criteria for assessment	Descriptors	Weight	Data reliability 1 (high) - 5 (low)	Vulnerability score 1 (high) - - 5 (low)
Natural environment	Natural hazards	Are natural hazards known and mapped ?	Hazard maps availability	Binary	Yes/no	1	3	5
			Hazard maps scale	Scale/detail with respect to planning decisions	County level, neighbourhood level, single bdg. level	1		1
			Considers domino effects	Consider potential na-tech	Yes/No, only partially	1	2	1
			Hazard maps consider climate change	Binary	Yes/No	0,5	3	3
		Are hazards monitored ?	Does an instrumented flood detection and monitoring system exist. What is its geographical density/coverage ?	Binary, density per square km, % area covered	Yes/no, nos. per sq km, % <30%, 30-60%, >60%	1	4	2
		Integration of weather, flood detection systems with hydrologic and hydraulic flood forecast models	Does integration exist, how advanced is it, what level of accuracy/reliability achieved ?	Binary, expert judgement about the level of advancement of integration compared with state-of-the-art; back analysis ?	Yes/no, good/poor, good match between forecast and actual floods, false warning rate (FAR) (%), Probability of Detection (POD) %, Brier Score	1	2	2
		Flood forecasting	Flood forecasting capability	Forecast resolution capacity	Low, medium, high	1	3	2
		Flood warning	Is severe weather warning integrated with flood warning to lengthen overall flood warning lead time ?	Binary	Yes/no	1	2	2
			Flood warning timeliness	Flood warning lead time	Very short (<30 mins); short (31-180 mins); medium (181-12hrs)' long (>12hrs)	1	3	1
		Structural flood defences (i.e. large scale defences)	Do structural defences exist. What is the design standard for protection ?	Binary; Return Period for which protection is set	Yes/no, 50,80, 100, >100 yrs	1	5	3
			Do protection standards take climate change into account ?	Binary	Yes/no	0,5	5	3
			Condition of defences	Is condition assessed regularly (a) point installations (binary) (b) linear institutions (binary) ?	(a) Yes/no, % in excellent, good, poor condition (b) Yes/no % in excellent, good, poor condition	1	5	.
			Maintenance	(a) Does a systematic plan exist for maintenance (binary) (b) is maintenance budget protected (binary)	(a) Yes/no (b) Yes/no	0,5	5	1
			Is space available to construct, reconstruct or realign defences ?	Binary	Yes/no	0,5	5	.
			Flood retention areas (a) Do they exist ? (b) Does land use planning allow for potential retention areas to be protected ? Are natural flood buffer zones maintained and reinstated ?	(a) and (b) binary, binary	Yes/no	0,5	5	1

Table 7: Mitigation capacity – assessment of the natural environment at Prefecture to National scale (i.e. Ilia and Greece) for floods

The first system to be assessed is the **natural environment** (

	System	Aspect	Parameters	Criteria for assessment	Descriptors	Weight	Data reliability 1 (high) - 5 (low)	Vulnerability score 1 (high) - - 5 (low)
Natural environment	Natural hazards	Are natural hazards known and mapped ?	Hazard maps availability	Binary	Yes/no	1	3	5
			Hazard maps scale	Scale/detail with respect to planning decisions	County level, neighbourhood level, single bdg. level	1		1
			Considers domino effects	Consider potential na-tech	Yes/No, only partially	1	2	1
			Hazard maps consider climate change	Binary	Yes/No	0,5	3	3

Are hazards monitored ?	Does an instrumented flood detection and monitoring system exist. What is its geographical density/coverage ?	Binary, density per square km, % area covered	Yes/no, nos. per sq km, % <30%, 30-60%, >60%	1	4	2
Integration of weather, flood detection systems with hydrologic and hydraulic flood forecast models	Does integration exist, how advanced is it, what level of accuracy/reliability achieved ?	Binary, expert judgement about the level of advancement of integration compared with state-of-the-art; back analysis ?	Yes/no, good/poor, good match between forecast and actual floods, false warning rate (FAR) (%), Probability of Detection (POD) %, Brier Score	1	2	2
Flood forecasting	Flood forecasting capability	Forecast resolution capacity	Low, medium, high	1	3	2
Flood warning	Is severe weather warning integrated with flood warning to lengthen overall flood warning lead time ?	Binary	Yes/no	1	2	2
	Flood warning timeliness	Flood warning lead time	Very short (<30 mins); short (31-180 mins); medium (181-12hrs)' long (>12hrs)	1	3	1
Structural flood defences (i.e. large scale defences)	Do structural defences exist. What is the design standard for protection ?	Binary; Return Period for which protection is set	Yes/no, 50,80, 100, >100 yrs	1	5	3
	Do protection standards take climate change into account ?	Binary	Yes/no	0,5	5	3
	Condition of defences	Is condition assessed regularly (a) point installations (binary) (b) linear institutions (binary) ?	(a) Yes/no, % in excellent, good, poor condition (b) Yes/no % in excellent, good, poor condition	1	5	.
	Maintenance	(a) Does a systematic plan exist for maintenance (binary) (b) is maintenance budget protected (binary)	(a) Yes/no (b) Yes/no	0,5	5	1
	Is space available to construct, reconstruct or realign defences ?	Binary	Yes/no	0,5	5	.
	Flood retention areas (a) Do they exist ? (b) Does land use planning allow for potential retention areas to be protected ? Are natural flood buffer zones maintained and reinstated ?	(a) and (b) binary, binary	Yes/no	0,5	5	1

Table 7). Essentially assessment of this system is about the degree of advancement of the current flood detection, forecasting and warning system and structural flood defence measures. Major concerns here are whether or not the flood hazard is currently mapped, monitored, forecast and warned about, and whether or not there are structural flood defence measures in place. Also important here is the degree to which weather and flood detection and monitoring is integrated with flood forecasting using flood forecasting models and the level of capability associated with these processes. Although flood hazard maps apparently now exist for the case study area (thus vulnerability is low (i.e. 5)), and although an Hellenic meteorological service provides weather forecasts, the remaining elements of this system require much greater development (e.g. the river level monitoring network is currently sparse) to create an advanced flood forecasting and warning system capable of reliably warning flood risk area occupants with sufficient lead time for them to respond appropriately. We therefore consider the level of existing mitigation capacity under the natural environment system to be rather low and thus vulnerability is mostly scored as high (i.e. 1)

As far as the **built environment** system is concerned (

	System	Aspect	Parameters	Criteria for assessment	Descriptors	Weight	Data reliability 1 (high) - 5 (low)	Vulnerability score 1 (high) - - 5 (low)
Built environment	*Exposure & vulner/ty of the built env/ment*	Is exposure and and vulnerability considered and acted on in plans ?	Vulnerability assessment of exposed built stock	Binary, updating frequency	Yes/no, frequency yrs	1	5	1
			Risk maps and scenarios, including enchained events	Binary, by risk/hazard zone	Binary	1	3	1
	Risk and tools for risk	Do rules for mitigation exist ? What is their expected efficacy/quality ?	Vulnerability and exposure assessment considered when ordinary plans are formulated (example land use)	Binary; mode of inclusion	Yes/no, only formally/substantially with limitations and specific requirements	1	5	1

		Building codes/rules	Binary, updated, extent of compliance	Yes/no, judgement of effectiveness upon 'age' of rules with respect to state-of-the-art, good/poor compliance	1	3	2
		Rules for retrofitting	Binary	Yes/no	0,5	5	.
		Flood resilience built into new projects and programmes	Yes/no		1	5	.
		Traditional building practice based on hazard knowledge	Binary; capacity to reproduce traditional techniques correctly	Yes/no; judgement about the capacity to conform to the 'code or practice'	1	3	2
		Maintenance of building stock	Binary; financial incentives	Yes/no; exist/not foreseen	0,5	5	.
		Land use plans embedding risk mitigation and vulnerability reduction	Binary; expert judgement	Binary; sect oral/comprehensive; specific/generic	1	4	1
		Implementation capacity	Binary; frequency of inspections; trained personnel for inspections	Yes/no; availability of budget for personnel to advise and inspect	1	5	1
		Integration with other measures (e.g. insurance)	Binary	Yes/no; what conditions ?	0,5	5	.
		Accessibility projects in hazardous zones	Binary	Yes/no	1	5	.

Table 8), we also assess vulnerability to be high because of the exposure of properties and people to floods and vulnerability of the built environment to the kind of flooding characteristic of this region. Here it is important to point out that we believe that rather less than 10% of the total number of properties and people living in the case study area are at direct risk of flooding (others may be at risk of disruption from flooding which is an indirect consequence of inundation). However, of those who are at direct risk we believe that the general lack of structural flood defence measures coupled with lack of building resilience (resulting for example from application of building codes designed to make properties flood resilient when constructed), and further coupled with the fact that floods are likely to be high energy, destructive flash floods, means that mitigation capacity is currently low and vulnerability is high. However this must be viewed in the context of the flood hazard not being spatially extensive in the case study area and not affecting anything more than less than 10% of the population and buildings. Generally Greece has relaxed building and planning regulations with a comparatively high proportion of 'illegal' buildings. This generally reinforces vulnerability rather than increasing mitigation capacity.

	System	Aspect	Parameters	Criteria for assessment	Descriptors	Weight	Data reliability 1 (high) - 5 (low)	Vulnerability score 1 (high) - - 5 (low)
Built environment	Exposure & vulner/ty of the built env/ment	Is exposure and and vulnerability considered and acted on in plans ?	Vulnerability assessment of exposed built stock	Binary, updating frequency	Yes/no, frequency yrs	1	5	1
			Risk maps and scenarios, including enchained events	Binary, by risk/hazard zone	Binary	1	3	1
	Risk and tools for risk mitigation	Do rules for mitigation exist ? What is their expected efficacy/quality ?	Vulnerability and exposure assessment considered when ordinary plans are formulated (example land use)	Binary; mode of inclusion	Yes/no, only formally/substantially with limitations and specific requirements	1	5	1
			Building codes/rules	Binary, updated, extent of compliance	Yes/no, judgement of effectiveness upon 'age' of rules with respect to state-of-the-art, good/poor compliance	1	3	2
			Rules for retrofitting	Binary	Yes/no	0,5	5	.
			Flood resilience built into new projects and programmes	Yes/no		1	5	.
			Traditional building practice based on hazard knowledge	Binary; capacity to reproduce traditional techniques correctly	Yes/no; judgement about the capacity to conform to the 'code or practice'	1	3	2

		Maintenance of building stock	Binary; financial incentives	Yes/no; exist/not foreseen	0,5	5	.
		Land use plans embedding risk mitigation and vulnerability reduction	Binary; expert judgement	Binary; sect oral/comprehensive; specific/generic	1	4	1
		Implementation capacity	Binary; frequency of inspections; trained personnel for inspections	Yes/no; availability of budget for personnel to advise and inspect	1	5	1
		Integration with other measures (e.g. insurance)	Binary	Yes/no; what conditions ?	0,5	5	.
		Accessibility projects in hazardous zones	Binary	Yes/no	1	5	.

Table 8: Mitigation capacity – assessment of the built environment at Prefecture to National scale (i.e. Ilia and Greece) for floods

System	Aspect	Parameters	Criteria for assessment	Descriptors	Weight	Data reliability 1 (high) - 5 (low)	Vulnerability score 1 (high) - - 5 (low)
Infrastructure and production sites / Critical infrastructure	Is vulnerability of critical infrastructure assessed and acted upon ? Particularly with respect to na-techs and enchained effects on dependent systems ?	Vulnerability assessment of CI	Binary; updating frequency	yes/no; anytime new project/repair or only after floods	1	5	1
		Maintenance programmes embedding mitigation	Binary	Yes/no	1	5	1
		New projects based on hazard/risk assessment	Binary	Yes/no	1	5	1
	Is the vulnerability of production sites considered particularly with respect to potential na-techs ?	Level of coordination among stakeholders	Binary	Yes/no	1	5	1
		Vulnerability assessment of production sites	Binary; updating frequency	Yes/no; anytime new project/repair or only after floods	1	5	1
		Retrofitting measures for existing production sites	Binary	Yes/no	0,5	5	1
		New projects based on risk assessment	Binary	Yes/no	1	5	1
		Na-tech explicitly accounted for in hazardous installations emergency plans	Binary; expert judgement on quality	Yes/no; low/medium/high	1	4	2
		Commercial flood insurance	Binary; extent of coverage	Yes/no; low/medium/high	0,5	5	.

Table 9: Mitigation capacity – assessment of infrastructures and production sites at Prefecture to National scale (i.e. Ilia and Greece) for floods

Infrastructure and production sites are equally vulnerable to floods because mitigation capacity is rather low i.e. few attempts have been made so far to locate critical infrastructures and production sites out of the way of flood risks (

System	Aspect	Parameters	Criteria for assessment	Descriptors	Weight	Data reliability 1 (high) - 5 (low)	Vulnerability score 1 (high) - - 5 (low)
Infrastructure and production sites / Critical infrastructure	Is vulnerability of critical infrastructure assessed and acted upon ? Particularly with respect to na-techs and enchained effects on dependent systems ?	Vulnerability assessment of CI	Binary; updating frequency	yes/no; anytime new project/repair or only after floods	1	5	1
		Maintenance programmes embedding mitigation	Binary	Yes/no	1	5	1
		New projects based on hazard/risk assessment	Binary	Yes/no	1	5	1
	Is the vulnerability of	Level of coordination among	Binary	Yes/no	1	5	1

	production sites considered particularly with respect to potential na-techs ?	stakeholders					
		Vulnerability assessment of production sites	Binary; updating frequency	Yes/no; anytime new project/repair or only after floods	1	5	1
		Retrofitting measures for existing production sites	Binary	Yes/no	0,5	5	1
		New projects based on risk assessment	Binary	Yes/no	1	5	1
		Na-tech explicitly accounted for in hazardous installations emergency plans	Binary; expert judgement on quality	Yes/no; low/medium/high	1	4	2
		Commercial flood insurance	Binary; extent of coverage	Yes/no; low/medium/high	0,5	5	.

Table 9). Flood risk vulnerability assessment is not at all commonly utilised and acted upon. Commercial flood insurance is not at all widespread. Again this high vulnerability must be viewed in the context of Ilia having rather few production sites, certainly of a manufacturing kind. Only 0.48% of the total buildings in the prefecture of Ilia were manufacturing premises in the 2000 buildings census. Those production sites which exist tend to be in the agricultural or service sectors. The case study area is relatively remote from the economic and population core of Greece and is currently connected to these by relatively poor transportation systems. These are the conditions in which infrastructure damage (e.g. road and bridge damage or loss owing to floods) produces heightened vulnerability.

The final system to be considered is the **social system** (Table 10). Awareness of the flash flood risk in the case study area is reportedly low, public access to flood maps is underdeveloped, flood insurance is underdeveloped and there is little engagement in the community in response to flood risks and flood prevention. Again, these parameters indicate that flood vulnerability is high and mitigation capacity is low. Finally, one factor which works in the opposite direction and serves to bolster mitigation capacity is the fact that this region has many non-permanent occupants who live in other parts of Greece (e.g. Athens) from which they can call on extra resources in times of difficulty.

System		Aspect	Parameters	Criteria for assessment	Descriptors	Weight	Data reliability 1 (high) - 5 (low)	Vulnerability score 1 (high) - - 5 (low)
Social system (agents)	People/individuals	Parameters area addressed to evaluate the capacity of individuals living in hazard prone areas coping with hazardous events, which largely depends on the perception of risk conditions before the event occurs	Risk perception and awareness	Questionnaires, surveys, judgement after event	Negligible or low/average/good	1	5	1
			Access to flood information including flood maps, explanation of warning codes, appropriate actions	Binary; map quality	Yes/no; good/fair/poor	1	5	1
			Flood insurance	Binary; coverage	Yes/no; good/fair/poor	1	5	1
			Individual preparedness	Regarding specific self-protection measures & emergency plans	Low/medium/high	1	5	1
	Community and institutions	Parameters area addressed to evaluate the involvement of a community into decision-making processes related to risk prevention and mitigation, the capacity of institutions to improve risk awareness through information and education campaigns and the level of cooperation among different institutions in charge of risk prevention and mitigation	Training and experience of population or communities	Qualitative judgement	Low/medium/high	1	5	1
			Participation in development and prevention/mitigation strategies and plans including evacuation plans	Binary; level of involvement	Yes/no; only formal; encouraging community participation	1	5	3
			Level of social cohesion or community spirit	Qualitative judgement	Low/medium/high	0,5	5	1
			Education programme & media campaigns	Binary; frequency	Yes/no; regular; only occasionally	1	3	3
			Capacity to invest in mitigation	Qualitative judgement	Low/medium/high	0,5	5	1
			Coordination and cooperation among institutions in charge of risk prevention/mitigation	Qualitative judgement	Low/medium/high	1	5	2
	Economic stakeholders	Are economic stakeholders willing/able to reinvest in affected areas?	Long term vision	Existence of strategic development/land use plans	Yes/no; only formal	1	4	3
			Insurance coverage for direct damage and consequential loss	Binary; % coverage	Yes/no; % without insurance	1	3	2
			Dependence of economic actors on loss of environmental goods	Prevalent tourist activity, agricultural activity	%	1	3	3
			Access and information about funds for reconstruction	Degree	High/medium/low	1	4	4
			Degree of diversification and capacity to spread risks	Degree	High/medium/low	1	3	2
			Access to funds from outside of the region	Binary	Yes/no	1	2	4

Table 10: Mitigation capacity – assessment of the social system at Prefecture to National scale (i.e. Ilia and Greece) for floods

4.3 Physical vulnerability

4.3.1 Forest fires

Physical vulnerability is about assessing the interaction of ecosystems with the forest fire hazard, as well as estimating the merits of mitigation measures. Regarding the latter, vulnerability is high (scored at the highest level), due to the fact that specific areas were burnt in an effort to contain the spread of fire. On the other hand, if land cover inflammability is taken into account and be assessed in terms of surface fuels, tall tree crowns and tree types, vulnerability is scored 3 or 4 (ie. medium to low). This is because there is only a limited number of communities that exhibit high percentage of areas covered by flammable vegetation (see Figure 16). In addition, neither the presence of tall tree crowns nor that of conifers is high.

	System	Aspect	Parameters	Criteria for assessment	Descriptors	weight	score (1=high; 5=low)	Application to Ilia case study
Natural environment	*Natural ecosystems*	Do natural environments interact significantly with the hazard?	land cover inflammability	Surface fuels	Only needle or leaf litter on the ground; sparse low vegetation; tall dense phrygana or shrubs	1	3	The percentages of this land cover (conifers-needle and broadleaved-leaf) to the municipalities were 3.6, 9.1 and 8.3% respectively. This is a parameter significantly varies both in space and time. Overall, 16 communities exhibit high or very high percentage of flammable vegetation (see maps).
				Existence and cover of tall tree crowns	No tree crowns; tree crown cover of <40%; tree crown cover >= 40%	1	4	As tree crown cover I considered conifers and broadleaved trees. Consequently the percentages of this land cover to the municipalities are 3.6, 9.1 and 8.3%.
				Type of trees		1	3	3.3, 9.1 and 7.4 % of the area was covered by conifers; 0.3, 0.0 and 0.9 % of the municipalities area was occupied by broadleaved trees
		Are natural ecosystems vulnerable to mitigation measures taken particularly during the emergency phase?	How natural ecosystems may be impacted by mitigation measures?	Binary	Yes/no	1	1	Specific areas of Kaiafa and Ancient Olympia were intentionally burnt in order to stop the fire

Table 11: Physical vulnerability in Ilia 2007 forest fires – the natural environment system

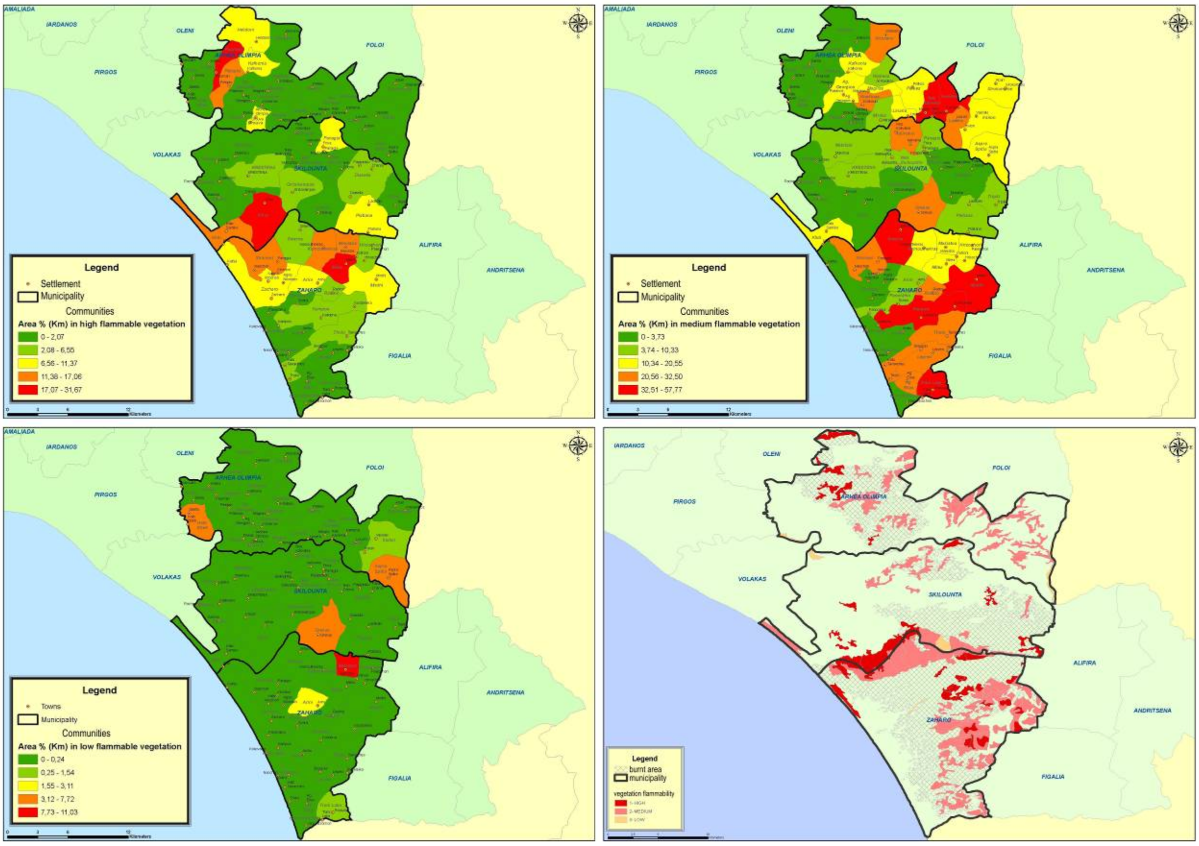

Figure 16: Vegetation flammability – areas with high-medium-low flammable vegetation in the forest fires study area

Dealing with the factors that make the built environment vulnerable to forest fires (Table 12), only gas stations have been considered, using the proximity of gas stations to adjacent villages as a proxy. As it is shown in Figure 17, the majority of gas stations are located along main roads and mainly in the coastal zone (which is crossed by the national road) or close to the Ancient Olympia site, resulting in high mean distances from population centres. Therefore the use of this parameter indicates a rather low level of exposure and vulnerability (scored 4). On the contrary, the scattered built pattern that is a feature of the coastal zone is contributing to high level of exposure, as does the relatively deep mean slope of rural settlements (Figure 18). Last, although archaeological sites are not scattered in the area, the important site of the Ancient Olympia –a site that was supposed to be well protected against fire hazards– is a critical factor that further increases vulnerability of the system.

System	Aspect	Parameters	Criteria for assessment	Descriptors	weight	score (1=high; 5=low)	Application to Ilia case study
Built environment *Exposure and vulnerability of built environment*	What are the factors that make 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	2	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). See also comment for built pattern below.
		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	4	Only gas stations are considered (see map), which constitute a dangerous use in a few specific places.
		Morphological features of settlements	Influence of the slope of the surrounding area	Slope i <5%/ 5% <= i < 20 / Slope >= 20%	0,5	2	10 settlements have a mean slope lower than 5%, 44 have a mean slope between 5 and 20 and 38 settlements have a mean slope higher than 20%.
		Historic sites (archeological) and buildings (monuments and museums) in the hazardous areas	Binary; extent and relevance	no/yes; dimension; minor/relevant/very relevant	1	1	YES. Though sites of historic significance are few, their importance is exceptional.
		If previous parameter YES, then Level of protection	Binary and quality	yes/no; effective/ineffective	1	1	Ineffective protection.
		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	2	In lowland coastal planes (eg. Zaharo) the built pattern is scattered; in high altitude areas the pattern is more dense.

Table 12: Physical vulnerability in Ilia 2007 forest fires – the built environment system

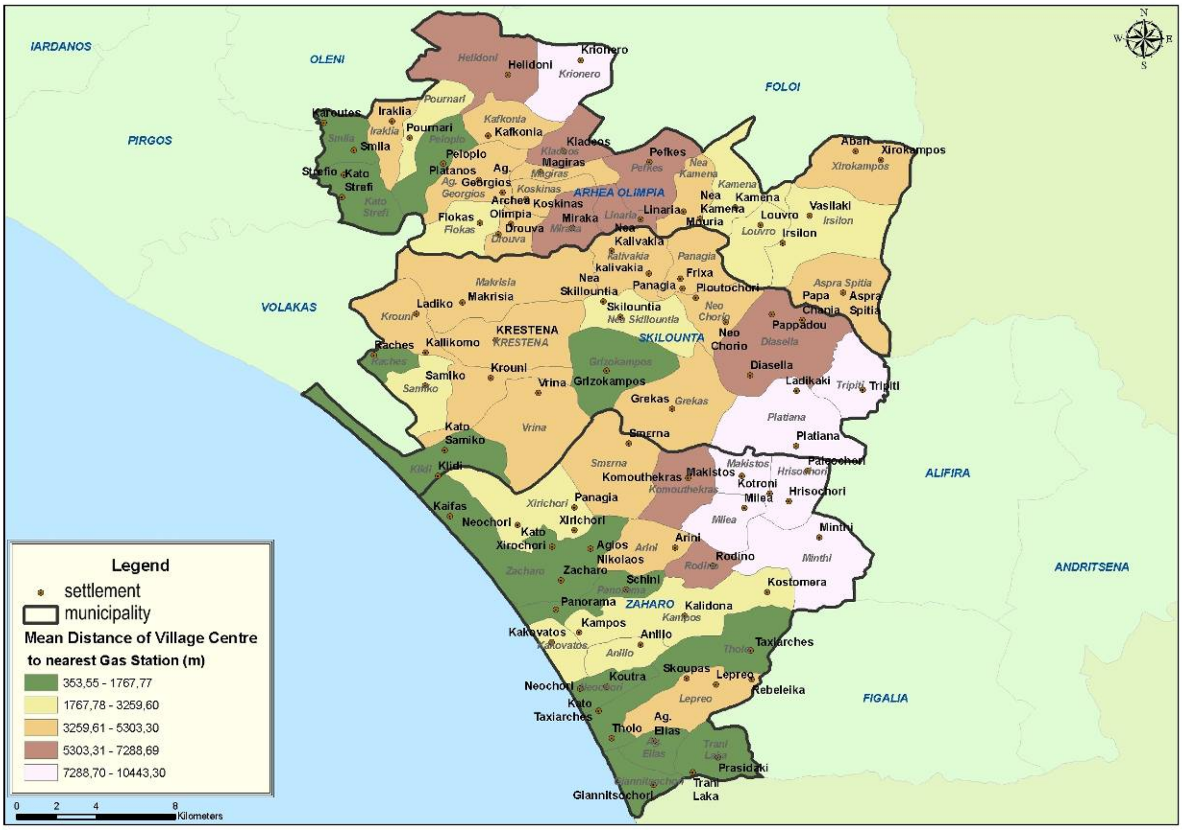

Figure 17: Mean distance of village centre to nearest gas station in the forest fires study area (community level)

Figure 18: Mean slope within a 2.000 m. buffer zone of settlements in the forest fires study area (community level)

	System	Aspect	Parameters	Criteria for assessment	Descriptors	weight	score (1=high; 5=low)	Application to Ilia case study
Infrastructure and production sites	*Critical infrastructures*	What are the factors that make critical infrastructures vulenrable (mainly lifelines)	Vulnerability assessment of critical infrastructure	water system pressure	normal/ too low pressure for hydrants	1	3	Normal pressure. Every year, during wintertime the Fire Brigade checks if the hydrants work. In case of problems, they inform the Municipality for restoration
				self eater tank	available/not available	1	4	Forest Service: Self eater tanks available in every village that can be used for firefighting. Forest Service hasconstructed 10 tanks of 100 tonnes. Zaharo Municipality: Self eater tanks available also for citizens Krestena Municipality: Self eater plastic tanks available constructed by the Fire Brigade, the Forest Service and donations of Municipalities. They are located in central places of main roads and can also be used by citizens.
			roads	interaction with fuel	large road sections in open zones/in the middle of fuel areas	1	2	The length of the roads (all kinds of roads, national – local etc) which pass through flammable land cover (mainly forests) has been calculated. These lengths for the three cases study municipalities are 18.4 km, 27.0 km and 5.6 km respectively.
	Production sites	What are the 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	-	Irrelevant (apart from hotels)
			Vulnerability due to dependency on lifelines	depending on the degree of dependance upon external vulnerable lifelines	self eater tank available/not available	1	-	Irrelevant

Table 13: Physical vulnerability in Ilia 2007 forest fires – infrastructures and production sites

System		Aspect	Parameters	Criteria for assessment	Descriptors	weight	score (1=high; 5=low)	Application to Ilia case study
Social system (agents)	People/individuals	What are the 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	4	Most of the houses within the study area (especially in the northern part) are concentrated in villages. On the other hand at the southern part along the coastline there are some isolated houses.
			Preparedness	self protection means	hydrants at home/lack of hydrants	1	1	NO
				self protection against smoke	availability of masks/lack of	1	1	NO
			Age; mobility impairment, other impairment	difficulties to comply with evacuation orders; difficulties in escaping	> 65; number of handicapped	1	2	19,11% of Ilia population is over 65 years of age. In our area case this index is even higher, due to its rural character
	Community and institutions	What are the factors that may lead to large number of victims?	Distance from firefighting resources	time of arrival	within 30 min; > 1 hour	1	3	Time for the first vehicle is always less than 30min
			Availability of trained personnel	professional training in the community	firefighters (professional+volunteers)/only professional	1	2	Professional & Volunteers

Table 14: Physical vulnerability in Ilia 2007 forest fires – the social system

As far as **infrastructures** are concerned (Table 13), we find out that vulnerability of critical infrastructure is assessed as medium to low. The exception here is roads passing through highly exposed forest area (Figure 19). When it comes to **production sites**, vulnerability cannot be assessed, because all relevant parameters cannot be applied to this particular hazard and area (see also notes in mitigation matrix below – Table 5). On the other hand, the physical vulnerability of the social system is rather high, if we take into account criteria such as self protection means, the aging rural population and the high ratio of vonunteers among trained fire-fighting staff (Table 14). What actually lesser vulnerability is availability of fire-fighting resources (in terms of response time of vehicles – scored 3) and limited sparse population in the northern and mountainous parts of the area (score = 4).

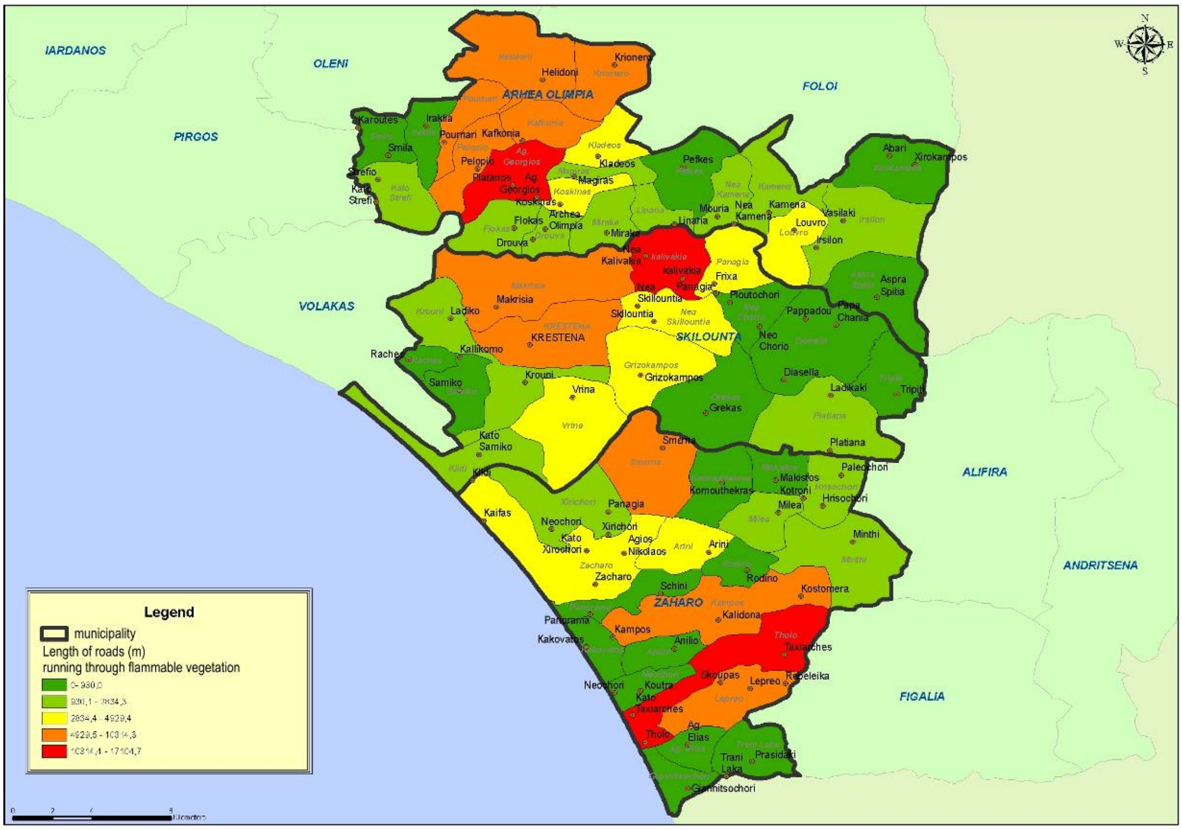

Figure 19: Length of roads running through flammable vegetation in the forest fires study area (community level)

4.3.2 Floods

Physical vulnerability concerns the degree to which the natural environment, buildings, infrastructure, people and social systems are vulnerable to the physical effects of flooding. The case study area appears to exhibit a range of vulnerabilities from low, to medium and to high. Again vulnerability has been scored in a manner which reflects the assessed degree of vulnerability of buildings etc. to flood hazards without reducing these vulnerability values to take into account the proportion of buildings etc. exposed to the flood risk, see Table 2.

Taking the **Natural Environment** system first, there is a lack of specific knowledge about how physically vulnerable or resilient olive trees and other crops found in the region are to flooding. However, although flood durations are likely to be short, flooding is likely to be of a high energy type which can be destructive of land and soil on which trees and crops grow. Although there may be built-in natural resiliences, in the short term we believe that physical vulnerability is quite high. We do not believe that the natural environment is particularly vulnerable to mitigation measures and this is reflected in the low score attached to this aspect (i.e. 5) (see Table 15).

	System	Aspect	Parameters	Criteria for assessment	Descriptors	Weight	Data reliability 1 (high) - 5 (low)	Vulnerability score 1 (high) - - 5 (low)
Natural environment	*Natural ecosystems*	Fragility to potential effects of floods	Are different crops/agric/ natural veg vulnerable ?	Height of water, quality of water, debris load, flood duration	Flood depth, concentration of contaminants, days	0,5	3	2
		Can natural systems interact with hazards ?	Possibility of solid transport mechanisms ?	Binary/ expected volume of material	Yes/No and scale	1	2	2
		Are natural ecosystems vulnerable to mitigation measures taken particularly during the emergency phase ?	Is there a possibility of water diversion that will reduce water from needy areas ?	Binary	Yes/No and scale	0,5	3	5

Table 15: Physical vulnerability to stress (flood hazard) – assessment of the natural environment at Sub-Prefecture level

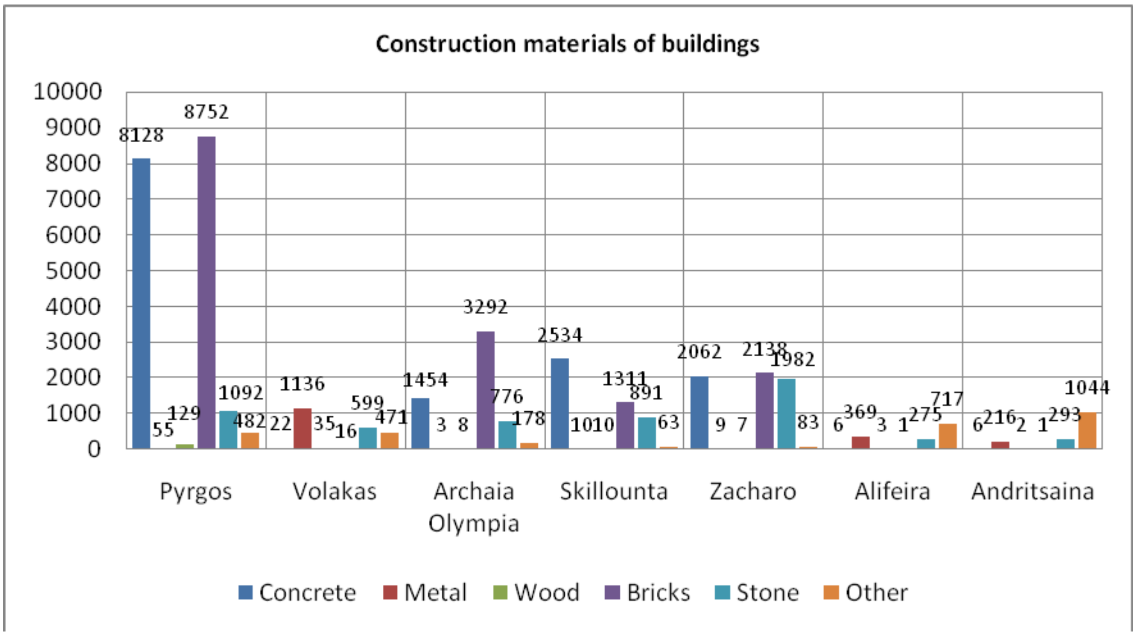

Figure 20: Frequency of construction materials used in the case study area

As far as the **Built Environment** is concerned, Figure 20 shows the construction materials used in the region (by municipality). Although spatially variable a high proportion of the study area's buildings are constructed of concrete, brick or stone (especially in the main urban centre of Pyrgos) and relatively few of timber. Generally (depending though on construction techniques and practices) these forms of construction are usually relatively robust in standing up to floods, but high velocity floods can cause semi or full destruction of such construction types in the more extreme flood conditions. This degree of physical resilience is modified to some extent by the presence of high velocity flood potential and this results in a vulnerability score of 3 in this case indicating a reasonable degree of resilience (Table 16).

System	Aspect	Parameters	Criteria for assessment	Descriptors	Weight	Data reliability 1 (high) - 5 (low)	Vulnerability score 1 (high) - - 5 (low)
Built environment	Exposure and vulnerability of the built environment: What are the factors that make buildings, the urban fabric and public facilities vulnerable to the stress ?	Buildings structural vulnerability	Construction materials and type, robustness	Timber/mud/stone/brick/concrete	0,5	4	3
			No. floors	1, 2, >2	1	2	1
			Level of 1st floor v. expected flood level	Lower, same, higher level	1	5	.
			Existence of basement	Yes/No	0,5	5	4
		Properties within flood risk zone	No. and type of properties	Nos and type frequency	1	5	.
		Position with respect to hazardous zones	Distance and position with respect to expected flood height	In the rapid inundation zone or at higher levels	1	4	3
		Content of bdgs.	Valuables on ground floor	Yes/No, type	1	2	1
		Vulnerability assessment of public facilities	As for buildings but distinguished by function		1	2	1
		Resistance and resilience of structural mitigation measures	Binary	Yes/No	1	4	1
		Camping in hazardous areas or facilitied	Binary and occupancy	Yes/No; number	1	2	1
		Non-structural mitigation measures (e.g. warning systems	Binary	Yes/no	1	5	2
		Proximity to hazardous land uses	Type of land use and distance	Estimate of distance e.g.<500m, 500m-1,000m	0,5	5	.
		Vulnerability of the urban fabric	Considering entire neighbourhoods, density etc.	Population density, high, medium, low	3	3	3
		Vulnerability of archaeological sites	Position and defences	In dangerous zone ? Yes/no; existence of defences, yes/no	0,5	3	3

Table 16: Physical vulnerability to stress (flood hazard) – assessment of the built environment at Sub-Prefecture level

On the other hand, the prevalence of single storey buildings in the seven municipalities, especially Pyrgos and Archea Olympia (Figure 21), indicates high physical vulnerability because single-storey buildings are the type most at risk from floods (other than those with basements which are not typical of this region and which are scored 4 i.e. low vulnerability). A physical vulnerability score of 1 has therefore been assigned using the number of floors as the criterion for assessment. Potentially this feature of building construction in Ilia makes the people occupying these buildings more physically vulnerable to flooding. There is a series of further built environment parameters which most commonly lead to high vulnerability scores including the prevalence of highly vulnerable camp sites in the region (although we have no data on their precise location vis-à-vis flood risk areas, but commonly camp sites are found in valley bottoms), the underdevelopment of public flood warnings and the general lack of physical resistance and structural flood protection measures. Archaeological sites are likely to be physically vulnerable and indeed the site at the sanctuary of Olympia has suffered flood and related erosion during a number of historic floods. This vulnerability is scored as 3 because it does not represent a human physical vulnerability to which highest scores are usually assigned, but it is a vulnerability even so.

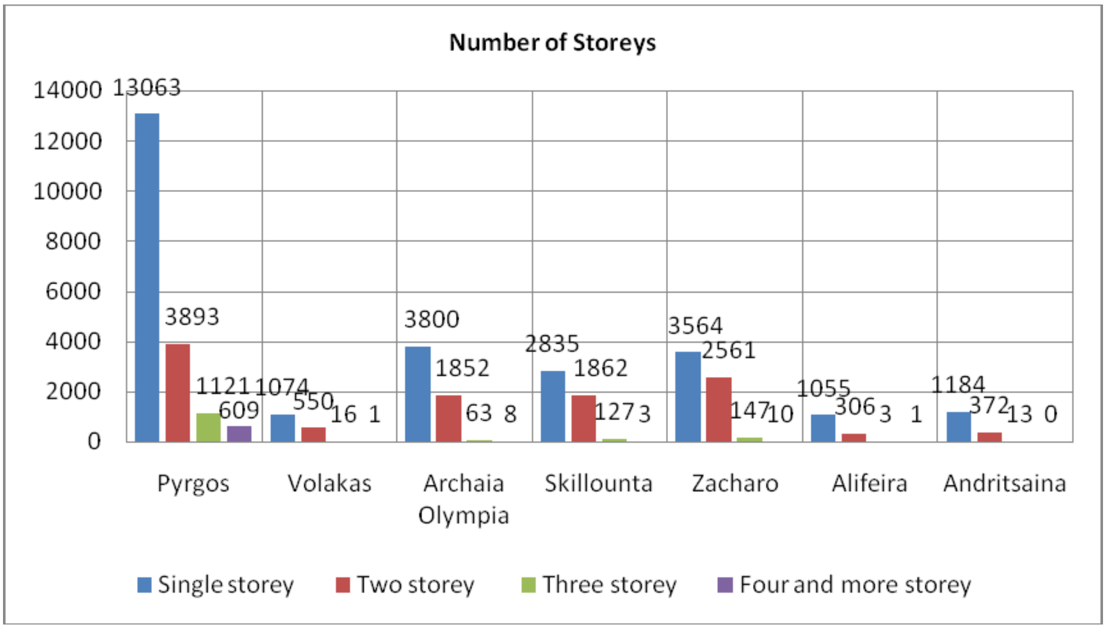

Figure 21: The high frequency of single storey buildings in the case study area

Under the **infrastructure and production site** system (

System		Aspect	Parameters	Criteria for assessment	Descriptors	Weight	Data reliability 1 (high) - 5 (low)	Vulnerability score 1 (high) - - 5 (low)
Infrastructure and production sites	*Critical infrastructures*	What are the factors that make critical infrastructure vulnerable (mainly lifelines) ?	Water treatment plants; electrical power plants; other lifelines plants	Distance and position with respect to expected flood	In the most critical flood zone, in a low risk flood zone	1	5	.
				Vulnerability assessments	Yes/no	1	5	.
				Maintenance routines	Yes/no	1	5	.
				Existence of emergency provisions to protect from floods	Yes/no	1	5	.
				Nat-techs considered in emergency procedures ?	Yes/no	0,5	5	-
		What are the factors that make production sites vulnerable (including an-tech potential) ?	Vulnerability assessment of production sites	Distance and position with respect to expected flood	In the most critical flood zone, in a low risk flood zone	1	5	-
				Existence of emergency provisions to protect structures from floods	Yes/no	0,5	5	1
				Maintenance routines	Yes/no	0,5	5	3
				Existence of provisions to protect stocked material & machinery	Yes/no	1	5	.
			Vuln. due to life- line dependence	Qualitative judgements	Low/med/high	0,5	3	2
			Proximity to dangerous l. use	Type of land use and distance	Low/med/high <500m, 500m-1,000m etc.	0,5	5	.

Table 17), the lack of data on critical infrastructure means that, unfortunately, currently no scores can be assigned. Research is probably required to assess the related parameters. The vulnerability of life-lines is scored as 2 because the case study area is relatively remote from the economic and infrastructural core areas of Greece and floods could easily sever lifelines (such as roads and supplies transported by road) causing serious problems.

As far as **social systems** are concerned (Table 18) the principal high vulnerabilities arise to people from the high frequency of single storey buildings, the lack of warning systems and lack of systematic flood vulnerability assessments. The lack of preparedness plans, age and mobility factors and the presence of tourists during tourist season are secondary factors (vulnerability scored 3, or 2 in the case of tourists) which exacerbate physical vulnerability.

System		Aspect	Parameters	Criteria for assessment	Descriptors	Weight	Data reliability 1 (high) - 5 (low)	Vulnerability score 1 (high) - - 5 (low)
Infrastructure and production sites	Critical infrastructures	What are the factors that make critical infrastructure vulnerable (mainly lifelines) ?	Water treatment plants; electrical power plants; other lifelines plants	Distance and position with respect to expected flood	In the most critical flood zone, in a low risk flood zone	1	5	.
Infrastructure and production sites	Critical infrastructures	What are the factors that make critical infrastructure vulnerable (mainly lifelines) ?	Water treatment plants; electrical power plants; other lifelines plants	Vulnerability assessments	Yes/no	1	5	.
Infrastructure and production sites	Critical infrastructures	What are the factors that make critical infrastructure vulnerable (mainly lifelines) ?	Water treatment plants; electrical power plants; other lifelines plants	Maintenance routines	Yes/no	1	5	.
Infrastructure and production sites	Critical infrastructures	What are the factors that make critical infrastructure vulnerable (mainly lifelines) ?	Water treatment plants; electrical power plants; other lifelines plants	Existence of emergency provisions to protect from floods	Yes/no	1	5	.
Infrastructure and production sites	Critical infrastructures	What are the factors that make critical infrastructure vulnerable (mainly lifelines) ?	Water treatment plants; electrical power plants; other lifelines plants	Nat-techs considered in emergency procedures ?	Yes/no	0,5	5	-
Infrastructure and production sites	Critical infrastructures	What are the factors that make production sites vulnerable (including an-tech potential) ?	Vulnerability assessment of production sites	Distance and position with respect to expected flood	In the most critical flood zone, in a low risk flood zone	1	5	-
Infrastructure and production sites	Critical infrastructures	What are the factors that make production sites vulnerable (including an-tech potential) ?	Vulnerability assessment of production sites	Existence of emergency provisions to protect structures from floods	Yes/no	0,5	5	1
Infrastructure and production sites	Critical infrastructures	What are the factors that make production sites vulnerable (including an-tech potential) ?	Vulnerability assessment of production sites	Maintenance routines	Yes/no	0,5	5	3
Infrastructure and production sites	Critical infrastructures	What are the factors that make production sites vulnerable (including an-tech potential) ?	Vulnerability assessment of production sites	Existence of provisions to protect stocked material & machinery	Yes/no	1	5	.
Infrastructure and production sites	Critical infrastructures	What are the factors that make production sites vulnerable (including an-tech potential) ?	Vuln. due to life- line dependence	Qualitative judgements	Low/med/high	0,5	3	2
Infrastructure and production sites	Critical infrastructures	What are the factors that make production sites vulnerable (including an-tech potential) ?	Proximity to dangerous l. use	Type of land use and distance	Low/med/high <500m, 500m-1,000m etc.	0,5	5	.

Table 17: Physical vulnerability to stress (flood hazard) – assessment of infrastructures and production sites at Sub-Prefecture level

System		Aspect	Parameters	Criteria for assessment	Descriptors	Weight	Data reliability 1 (high) - 5 (low)	Vulnerability score 1 (high) - - 5 (low)
Social systems (agents)	People/individuals	What are the factors that may lead to injuries and fatalities ?	Location with respect to vulnerable buildings, roads, industrial sites	People that may be trapped in flooded buildings of different types e.g. residential, public etc.)	Number of people in vulnerable buildings, location on maps	1	3	2
Social systems (agents)	People/individuals	What are the factors that may lead to injuries and fatalities ?	No. of storeys in buildings	Single storey buildings e.g. bungalows	% of housing stock which is one storey	1	2	1
Social systems (agents)	People/individuals	What are the factors that may lead to injuries and fatalities ?	Temporary houses of low robustness	Mobile homes etc.	No. living in these	1	5	.
Social systems (agents)	People/individuals	What are the factors that may lead to injuries and fatalities ?	Existence of high level exit routes and safe havens	Binary	Yes/no	0,5	5	2
Social systems (agents)	People/individuals	What are the factors that may lead to injuries and fatalities ?	Preparedness	Binary	Yes/no	1	4	2
Social systems (agents)	People/individuals	What are the factors that may lead to injuries and fatalities ?	Depth of flood dangerous for individuals	People know what to do in case of flood warning		1	3	1
Social systems (agents)	People/individuals	What are the factors that may lead to injuries and fatalities ?	Age, mobility, disability etc.	Curves: depths v individuals stability	No. of people, map locations	1	3	3
Social systems (agents)	People/individuals	How prepared are institutions ?	Existence of preparedness plans	Difficulties in complying with evacuation orders and in escaping	Yes/no	1	4	3
Social systems (agents)	Community and institutions	How prepared are institutions ?	Access to risk and warning info.	Binary	Yes/no or low/medium/high	1	5	1
Social systems (agents)	Community and institutions	How prepared are institutions ?	Vulnerability assessments	Qualitative judgement	Yes/no	1	5	1
Social systems (agents)	Community and institutions	What are the key factors that may lead to large numbers of victims ?	Population density in vulnerable areas	Maps	High/medium/low	1	3	3
Social systems (agents)	Community and institutions	What are the key factors that may lead to large numbers of victims ?	Nos. of visitors, tourists in vulnerable areas	Population density in different hazard areas	Number of tourists and visitors	1	3	2

Table 18: Physical vulnerability to stress (flood hazard) – assessment of the social system at Sub-Prefecture level

4.3.3 Seismic hazards

NATURAL ENVIRONMENT

The first system to be assessed concerns the natural ecosystem, which is, in comparison to the other systems, not highly vulnerable to seismic hazards. We therefore applied a low weight to this system.

Two aspects have been developed: the fragility of natural ecosystems to the potential effects of seismic hazards (landslides and tsunami) and to their secondary effects; the latter being estimated less critical than the first one. The assessment of these aspects have to be made according to the extent and relevance of the potentially impacted zone, which means that landslide and tsunami hazard maps as well as sensitive ecosystems maps are needed. It was not possible to get all these data for Ilia Prefecture and we therefore used the maximum vulnerability index. However, considering the little importance given to natural ecosystem, the total score is relatively low (Table 19).

	System	System weight	Aspect	Aspect weight	Parameters	Param weight	Criteria for assessment	Descriptors	Data availa.	Data qual.	Descri. score	Param score	Aspect score	System score	Time I	Time E	Space Micro	Space Meso	Space Macro
Natural environment	*Natural ecosystems*	*0,2*	Are natural ecosystems fragile to the potential effects of hazard?	*1*	extent and location of triggered landslides	*1*	degree and relevance of impacted zones	extended areas / few zones	*N*		*1*	*0,2*	*0,2*	*0,18*	1				1
					extent of potentially flooded zones by tsunami	*1*	degree and relevance of impacted zones	extended areas / few zones	*N*		*1*	*0,2*			1				1
			Are natural ecosystems fragile to the potential secondary effects of hazard(s)?	*0,75*	areas affected by landslides	*1*	number and extent	few/many; in remote areas/in crucial-central zones	*N*		*1*	*0,15*	*0,15*			1			1

Table 19: Ensure framework applied for seismic hazard to the natural ecosystem

BUILT ENVIRONMENT

The second system is related to the exposure and to the vulnerability of the built environment. The importance of this system is considered high since the potential building damages or collapses occurring during an earthquake are critical parameters.

This system is divided into two different aspects according to the time scale considered: the physical vulnerability or vulnerability to stress (impact time period) and the systemic vulnerability or vulnerability to losses (emergency time period).

Concerning the first aspect, four indicators have to be assessed: the vulnerability index of the residential buildings, the public facilities, the urban fabric and the historical buildings and monuments. Vulnerability assessment for aggregates is not yet fully developed: we then decided to weight this parameter with a low figure. It is worth noticing that these indicators can be seen as global indicators since they are themselves composed of many criteria. The presented framework for assessing physical vulnerability of built environment mentions the global indicators, which are based on a complete and specific study combining more than twenty criteria that make a building vulnerable to seismic hazard and described in a separate sub-matrix (see Table 24 below).

In the Ilia Prefecture case study, the physical vulnerability assessment of buildings was done through a standard statistical vulnerability analysis, the RISK-UE method (Milutinovic & Trendafiloski, 2003). The method, developed within a European project, is well adapted to the Greek context. However, it had to be simplified compared to the usual practice, due to the lack of field data. The physical vulnerability of buildings was analyzed here through a sampling technique, singling out classes of buildings showing the same features, and then extending vulnerability assessment from the sample buildings to the class they belong to.

Characteristics of buildings typologies, of their vulnerability and of damage figures were derived from valuable learning after the 1993 Pyrgos earthquake (Karantoni *et al.*, 1997). For instance, during the Pyrgos earthquake, the adobe buildings were heavily damaged. Some other studies in Thessaloniki (Pitilakis *et al.*, 2004) and in Lefkada Island (Karababa *et al.*, 2010) were used to estimate the vulnerability in classes of EMS98 intensity scale according to the type of material used and of the age of construction (see Table 20).

In addition to this information, statistical data from Greece (buildings census, 2000) were obtained. 88,634 buildings in the Prefecture are classified into 7 material groups: concrete, brick, stone, timber, metal, other and unknown (see Table 21). Buildings are also classed in periods of construction (see Table 22). However, it is not possible to link these two pieces of information. Some hypotheses were then necessary to use the census data. The results are shown in Figure 22. Due to the data that do not allow an analysis at the individual building scale, the results of the assessment could not be very detailed. One can nevertheless say that the municipalities with the highest vulnerability index (right image on Figure 22) seem to be located in the central part of the Prefecture, north from Pyrgos (corresponding to little rural towns where the majority of constructions are dated prior to 1945).

Census material type	Description	Age	Vulnerability class EMS 98	1993 Earthquake damages
Stone	Adobe	Prior to 1850	A	More of 80 % in D3
	Load-bearing stone masonry units	Prior to 1945	A-B	More of 50% in D2
Concrete	Reinforced concrete frame. Pre-code or 1959 code (low code)	After 1945 and prior to 1985	C	Masonry infills widespread cracking. 22 buildings with RC frames damaged
	Reinforced concrete frame. High code.	After 1985	D-E	
Brick	Unreinforced masonry. Load-bearing brick walls & RC slabs	After 1945	C	30% in D2
Wood	Timber frame structures		C	
Metal	Steel structure? or RC frames?		D	

Table 20: Classes of vulnerability according to the type and age of the material

Concrete	Metal	Wood	Bricks	Stone	Other materials	Not stated
14 769	21 962	376	15 836	25 815	8 868	1 488
16.57%	24.64%	0.42%	17.77%	28.97%	9.95%	1.67%

Table 21: Material of construction for Ilia Prefecture buildings

(after buildings census, 2000)

Before 1919	1919 - 1945	1946 - 1960	1961 - 1970	1971 - 1980	1981 - 1985	1986 - 1990	1991 - 1995	1996 and after	Under construction	Not stated
10 303	4 199	8 757	13 356	17 144	16 402	9 229	7 594	5 796	3 409	1 073
10.59%	4.32%	9.00%	13.73%	17.63%	16.86%	9.49%	7.81%	5.96%	3.50%	1.10%

Table 22: Period of construction of Ilia Prefecture buildings

(after buildings census, 2000)

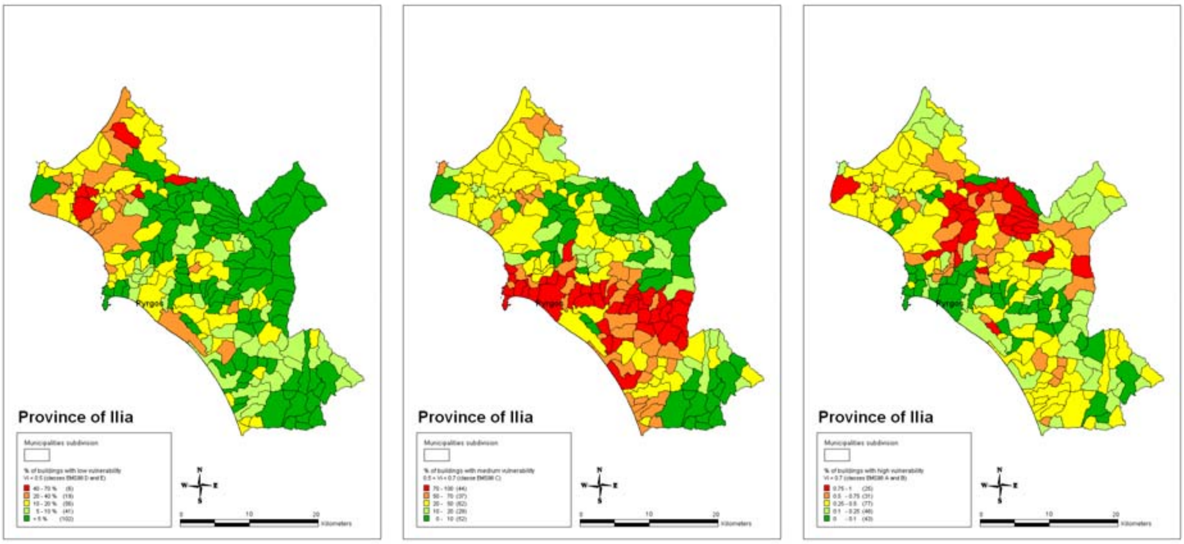

Figure 22: Vulnerability index Vi for the built environment in Ilia Prefecture

Because the vulnerability assessment can refer to different spatial units (individual building, urban district, whole area of investigation), the space scale is particularly important when filling in the matrix with the building vulnerability index. In our view, it does not make much sense to average the index obtained at the building scale on the whole Prefecture. This means that several matrices are needed for Ilia Prefecture, each of them being devoted to an area or to a group of buildings having a similar vulnerability. The information about the space scale for each indicator has also to be given to fully understand the real meaning of that score. For instance, the matrix given on Table 23 only concerns the group of buildings whose vulnerability index is 0.65. Please note that this index has been decreased to a value of 0.81 since the quality of the available data has been considered as fair. Concerning the urban fabric vulnerability index, we chose the highest vulnerability index (i.e. 1) since not enough data were available to carry out this analysis.

The second aspect that concerns the emergency period has been considered slightly less critical for the built environment than the vulnerability to the stress (impact period). The indicators for this aspect are less demanding than the first one since they do not represent global parameters. However, the lack of data (e.g. means of post seismic assessment) or the poor quality of available ones (e.g. quality and availability of shelters) require special caution regarding the scores obtained. Some information was indeed available at the national level (for instance data regarding the availability of post seismic buildings usability assessment) or was available only for the two main cities of the Prefecture i.e. Pyrgos and Vartholomio (information regarding the quality and the accessibility to the shelters). Estimations had then to be done for the other part (rural areas) of the region.

	System	System weight	Aspect	Aspect weight	Parameters	Param weight	Criteria for assessment	Descriptors	Data availa.	Data qual.	Descri. score	Param score	Aspect score	System score	Time I	Time E	Space Micro	Space Meso	Space Macro
Built environment	*Exposure and vulnerability of built environment*	*1*	What are the factors that make buildings, public facilities and the urban fabric vulnerable to the stress?	*1*	Vulnerability assessment of residential buildings (on the basis of available survey forms)	*1*	vulnerability of residential homogeneous urban sectors	vulnerability index (see vulnerability assessment matrix)	*Y*	*1,25*	*0,65*	*0,81*	*0,54*	*0,49*	**1**		**1**		
					Vulnerability assessment of public facilities (on the basis of available survey forms)	*1*	vulnerability of public facilities	vulnerability index (see vulnerability assessment matrix)	*Y*	*1,25*	*0,65*	*0,81*			**1**		**1**		
					Vulnerability assessment of the urban fabric	*0,15*	vulnerability of structural built aggregates	on the basis of: regularity; presence of strong inclination; presence of structural dishomogenity	*N*		*1*	*0,15*			**1**				**1**
					Vulnerability assessment of historical buildings / monuments	*0,4*	vulnerability of historical buildings / monuments	specific vulnerability indicators depending on the type of monument	*N*		*1*	*0,4*			**1**		**1**		
			What are the factors that make buildings, the urban fabric and public facilities vulnerable to losses?	*0,75*	Availability of rapid post seismic buildings usability assessment	*1*	forms pre-prepared and shared among all teams	yes/no	*Y*	*1,5*	*0,3*	*0,34*	*0,44*			**1**			**1**
							information computerized	yes/no	*N*		*1*	*0,75*				**1**			**1**
							existence of trained teams to assess post-earthquake building damage	yes/no	*N*		*1*	*0,75*				**1**			**1**
					Quality of temporary shelters (first emergency)	*0,5*	with heating or conditioning; sanitation; density	good / average / poor quality	*Y*	*1,5*	*0,3*	*0,17*				**1**			**1**
					Quality of more permenent temporary shelters	*0,75*	with heating or conditioning; sanitation; density; dimension; availability of services	good / average / poor quality	*Y*	*1,5*	*0,3*	*0,25*				**1**			**1**
					Accessibility to work sites from temporary shelters	*0,75*	distance; safe paths or roads; frequency of transportation	good / average / poor accessibility	*Y*	*1,5*	*0,6*	*0,51*				**1**			**1**
					Accessibility to public facilities from temporary shelters	*0,5*	distance; safe paths or roads; frequency of transportation	good / average / poor accessibility	*Y*	*1,5*	*0,6*	*0,34*				**1**			**1**

Table 23: Ensure framework applied for seismic hazard to the built environment

Criteria for assessment	
▪ identification of homogeneous urban sectors	▪ foundation depth and type
▪ definition of the building typologies	▪ soil morphology
▪ year of construction	▪ spans between resistant elements (mainly masonry)
▪ position inside the aggregate	▪ antiseismic joints
▪ interaction between buildings in aggegates	▪ soft stories
▪ numbers of floors	▪ regularity in plan
▪ roof connection to the building structure	▪ regularity in elevation
▪ roof weight	▪ added parts (balconies, chimneys)
▪ structural material	▪ maintenance
▪ connection between walls (only masonry): tied rods/angle bracket	▪ retrofitting programs
▪ floors rigidity	▪ non structural elements (equipment, furniture)

Table 24: Submatrix used to estimate the vulnerability index of buildings

INFRASTRUCTURES AND PRODUCTION SITES

Two systems are mentioned in the framework: the critical infrastructures (strategic infrastructures and lifelines) and the production sites.

As for the previous systems, the critical infrastructure one can be divided in two aspects according to the time period considered: the first one is related to the factors that make the infrastructure vulnerable and the second one, to the factors that can lead to infrastructure disruptions during the emergency period.

The first aspect can be evaluated through the vulnerability index of the strategic infrastructure and lifelines, which are both global indicators coming from a necessary extensive study. As the objective of the case study was not to complete a full analysis of seismic vulnerability, we decided to affect the same vulnerability index for strategic infrastructures as for current buildings. If more information had been available, an assessment especially devoted to each strategic infrastructure (e.g. hospitals, fire and police stations) would have been done. Table 25 depicts the matrix filled in for the case of a strategic infrastructure whose physical vulnerability index has been estimated to 0.65.

Concerning lifelines, we had no data on most of the networks (electricity, communication, gas network, drinking water and sewerage network); only sparse data on the road and rail network have been obtained. The scores for the vulnerability of those networks were then high; to decrease the score, one has to ensure the good conditions of these networks but such an assessment requires more information.

The systemic vulnerability of the critical infrastructures (second aspect) is described through several indicators. First, the redundancy in lifeline systems can be evaluated only for the transportation networks and seems rather good (the score of the indicator is then low); the same statement could be done for the degree of independency. The information gathered shows that the availability of emergency devices (generators, tanks,...) is disparate on the prefecture; some are available in Pyrgos, but for small villages, it is likely that no such devices will be accessible. Finally, the absence of continuity plan for the networks results in a high score.

Regarding the production sites, the framework contains parameters that can make the production sites vulnerable to the stress itself (at the impact time period) and that may lead to the stopping of the production during the emergency time period. However, contrary to the other systems for which some data were furnished, no information characterizing the production sites and their vulnerability were available. Moreover, for the physical vulnerability assessment of the production sites, we could not carry out the same methods than for the built environment due to the specific structures of the production sites. The highest scores were then chosen for all these parameters, meaning rather that more data should be gathered than a real high vulnerability.

	System	System weight	Aspect	Aspect weight	Parameters	Param weight	Criteria for assessment	Descriptors	Data avail.	Data qual.	Descri. score	Param score	Aspect score	System score	Time: I	Time: E	Space: Micro	Space: Meso	Space: Macro
Infrastructure and production sites	*Critical infrastructures*	*1*	What are the factors that make critical infrastructures vulnerable?	*1*	Vulnerability assessment of strategic infrastructures (hospitals, fire & police stations,…)	*1*	vulnerability of strategic infrastructures	vulnerability index (see vulnerability assessment matrix)	*Y*	*1,25*	*0,65*	*0,81*	*0,70*	*0,61*	**1**		**1**		
					Vulnerability assessment of lifelines	*0,75*	electricity (including nodes like power stations, transformers…)	derived from e.g. network caracteristics (buried/aerial, existence of shut-off valves/circuit-breakers…), conditions (age, degree of maintenance), network redundancy	*N*		*1*	*0,75*			**1**			**1**	
							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	*N*		*1*	*0,75*			**1**			**1**	
							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	*N*		*1*	*0,75*			**1**			**1**	
							communication (including nodes like base transceiver station,...)	derived from e.g. network caracteristics (buried/aerial,…), conditions (age, degree of maintenance), network redundancy	*N*		*1*	*0,75*			**1**			**1**	
							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	*Y*	*1,25*	*0,5*	*0,47*			**1**			**1**	
					Vulnerability due to physical interaction among lifelines	*0,75*	lifelines degree of connection	low/high	*Y*	*1,5*	*0,5*	*0,56*			**1**			**1**	
					Vulnerability due to lifeline connections to vulnerable buildings	*0,75*	lifelines close and attached to resistant/vulnerable buildings	yes/no	*N*		*1*	*0,75*			**1**			**1**	
			What are the factors that make critical infrastructures stop functioning?	*0,75*	Redundancy in lifelines systems	*1*	degree	low/high	*Y*	*1,5*	*0,5*	*0,56*	*0,53*			**1**		**1**	
					Degree of interdependance among lifelines	*0,75*	degree	low/medium/high	*Y*	*1,5*	*0,5*	*0,42*				**1**		**1**	
					Availability of emergency devices	*1*	binary (generators; tanks, etc)	yes/no	*Y*	*1*	*0,8*	*0,6*				**1**			**1**
					Continuity plan for lifelines, individually	*0,5*	binary and quality	yes/no; considers also induced hazards/ does not	*Y*	*1*	*1*	*0,38*				**1**			**1**

				and in a coordinated fashion													
				Degree of dependance of critical facilities from lifelines	1	degree	low/medium/high	Y	1,5	0,6	0,68				1		1
Production sites	0,75	What are the factors that make production sites vulnerable (including na-tech potential)?	1	Vulnerability assessment of production sites	1	as for public facilities		N		1	0,75			1		1	
				Potential na-tech due to stored materials, types of processes	1	binary, types of processes	yes/no; processes types	N		1	0,75	0,69		1		1	
				Vulnerability due to dependency on lifelines	0,75	dependance on lifelines	low/medium/high (existence of alternative solutions)	N		1	0,56			1		1	
		What are the factors that may lead to halting production?	0,5	Degree of dependance of production sites from lifelines	1	degree	low/medium/high	N		1	0,38		0,48		1	1	
				Accessibility to the plant and to markets	1	redundancy; quality of roads; usability; expected increase in travel time	redundant/not redundant; open/close roads; t.inc < 30 min/ t.inc > 30 min	N		1	0,38	0,28			1	1	
				Contingency plan for na-tech	0,5	binary	yes/no; considers all potential threats/does not	N		1	0,19				1	1	
				Business continuity plan	0,5	binary	yes/no	N		1	0,19				1	1	

Table 25: Ensure framework applied for seismic hazard to the infrastructure and production sites

SOCIAL SYSTEM

This system is divided in two subsystems, namely individuals and institutions, which have to be assessed both at the impact time and emergency periods (two aspects per subsystem). Unlike the built environment or the critical infrastructure parts, most of the indicators used to evaluate the social system are global parameters at the island scale or at an even bigger one.

As far as the individuals are concerned, the factors potentially leading to injuries and fatalities concern the people concentration, the preparedness, and social indicators that can bring about difficulties to comply with evacuations orders (age, impairments,...). The density is rather low inland and increases when getting closer to the coast. For these reasons, the vulnerability index has been considered average. However, the two other indicators are not known.

The second aspect regarding the individuals is made of indicators that may reduce the coping capacity during crisis. First it can be considered that the rural character of the prefecture can lead to potential difficulties in communication but the radio network is likely to be good, which can allow the access to understandable information even in remote areas. However, the trust in information providers is low in this Greek region. Finally, during the emergency period, the capacity to provide treatment in temporary camps is important and in some cities some volunteer doctor are trained for this purpose.

The subsystem dedicated to the institutions differentiates the factors that may lead to large number of victims (during the impact) and the ones that may hamper effective crisis management.

Regarding the first type of factors, one can say that emergency plans exist in the different municipalities. In 2011, the structure and responsibilities of Prefectures and Municipalities has changed into a new plan that includes unification of Prefectures and Municipalities. For the moment, no instructions and emergency plans have been set in case of an earthquake. However, in Pyrgos Municipality for instance, they work with the old emergency plan. Concerning the resources for search and rescue, some are available in Pyrgos but it is likely not to be the case in remote villages.

Concerning the second type of factors, one contingency plan is existing at least in the city of Pyrgos as well as established protocols for information sharing or for the use of resources to manage the crisis. Another piece of information concerns the overlapping responsibilities among agencies that are relatively significant, which possibly leads to some troubles during the emergency phase.

	System	System weight	Aspect	Aspect weight	Parameters	Param weight	Criteria for assessment	Descriptors	Data availa.	Data quality	Descri. score	Param score	Aspect score	System score	Time		Space		
															I	E	Micro	Meso	Macro
Social system (agents)	People / Individuals	0,75	What are the factors that may lead to injuries and fatalities?	1	People concentration in different zones in the hours of the day	1	degree of concentration in vulnerble locations/buildings	low/medium/high	Y	1,25	0,6	0,56	0,56	0,48	1				1
					Preparedness	1	previous training	yes/no	N		1	0,75			1				1
					Age; mobility impairment, other impairment	0,5	difficulties to comply with evacuation orders; difficulties in escaping	yes/no, number of people	N		1	0,38			1				1
			What are the factors that may reduce coping capacity during crisis?	1	Access to understandable information	0,75	binary	yes/no; centralized /at each group level (for example in each temporary camp)	Y	1,5	0,6	0,51	0,40			1			1
					Trust in information provisers	0,5	degree	low/medium/high	Y	1	1	0,38				1			1
					Preparedness to evacuation	0,5	individual plan	yes/no (like going to relatives)	N		1	0,38				1			1
					Presence of impaired groups (elderly, sick persons, etc.)	0,75	binary and quality of caring	yes/no; capacity to provide treatment in temporary camps/or not	Y	1,5	0,4	0,34				1			1
	Community / Institutions	0,75	What are the factors that may lead to large number of victims?	1	Existence of emergency plan and quality	0,75	binary; quality	yes/no; as judged by involved institutions	Y	1,25	0,6	0,42	0,30	0,37	1				1
					Availability of resources for search and rescue (lamps; cranes, special devices)	0,25	binary; number with respect to potentially damaged areas	yes/no; imemdiately accessible/remote; sufficient/not sufficient	Y	1,5	0,75	0,19			1				1
			What are the factors that may hamper effective crisis managem ent?	1	Existence of contingency plan fro threats at stake	0,75	binary; date of last production or update	yes/no; recent/old	Y	1,5	0,75	0,56	0,44			1			1
					Availability of quick post-event scenarios to be checked and used as a guidance in crisis managment	0,75	binary and quality	yes/no; considering also enchained effects and systemic damage/restricted to physical damage	N		1	0,56				1			1
					Training using the contingency plan	0,8	binary; frequency of training	yes/no; every two years/only occasionally	N		1	0,6				1			1
					Overlapping responsiblities among agencies	0,5	degree	Low/medium/high	Y	1,25	0,8	0,38				1			1
					Established protocols for information sharing	0,5	binary	yes/no	Y	1,5	0,4	0,23				1			1
					Established protocols for use of resources to manage the crisis	0,5	degree	yes/only partially/high	Y	1,5	0,6	0,34				1			1

Table 26: Ensure framework applied for seismic hazard to the social system

4.4 Systemic vulnerability

4.4.1 Forest fires

Systemic vulnerability vis-à-vis forest fires, as far as the **natural environment** is concerned, is rather low (Table 27). This is because a large percentage of the study area is highly or very highly susceptible to erosion and landslides after a fire event, an argument that has been confirmed in the case of Ilia (NTUA, 2008, though there is no specific study at hand about the actual effects of landslides). In turn, the factors that lead to the **built environment** being vulnerable to losses are related to availability of emergency resources snf to accessibility to vulnerable areas and public facilities. Although public facilities and equipment like movable devices are available and travel time for fire-fighting vehicles is short, it is the scattered pattern of buildings and the low quality of signs that increase vulnerability. On the other hand, specific structural features like these that have to do with the road network cannot be taken into account in assessing the vulnerability of the system, due to lack of data (Table 28).

	System	Aspect	Parameters	Criteria for assessment	Descriptors	weight	score (1=high; 5=low)	Application to Ilia case study
Natural environment	*Natural ecosystems*	Are natural ecosystems fragile to the potential secondary effects of hazard(s)?	soil deterioration	increase of erosion	<= 30 %; 30 x x < 50%; x>= 50%	1	1	A high percentage of the area (71.5, 74.9 and 53.9%) is characterized as of high and very high susceptible to erosion and landslides after a possible fire. These results are in agreement with the results of a study which was conducted for Zaharo after the 2007 fires by NTUA (2008).
			landslide hazard	degree of increase of landslide potential based on survey and expert judgment	low/medium/high	1	-	no data

Table 27: Systemic vulnerability in Ilia 2007 forest fires – the natural environment system

	System	Aspect	Parameters	Criteria for assessment	Descriptors	weight	score (1=high; 5=low)	Application to Ilia case study
Built environment	*Exposure and vulnerability of built environment*	What are the 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	3	YES
			Accessibility to vulnerable areas	Buildings density and proximity (follwoing Lampin-Maiillet et al., 2009)- total perimeter to be protected	very dense; dense, scattered; isolated	1	1	In lowland coastal planes (eg. Zaharo) the built pattern is scattered; in high altitude areas the pattern is more dense.
				Roads characteristics	Type of roads serving the various settlements	1	-	Insufficient data for conducting such estimations
					Plain roads/mountain roads	1	-	
				Signs in roads and streets (names, numbers, etc.)	yes/no	1	2	Low quality
			Accessibility to public facilities	existence of public facilities in the area	yes/no	1	3	YES (after the event)
				expected travel time	t > 30 min/ t <= 30 min	1	4	t <= 30 min
				road network to public facilities	as for accessibility to vulnerable areas	1	3	No data, appr. estimation

Table 28: Systemic vulnerability in Ilia 2007 forest fires – the built environment system

	System	Aspect	Parameters	Criteria for assessment	Descriptors	weight	score (1=high; 5=low)	Application to Ilia case study
Infrastructure and production sites	Critical infrastructures	What are the factors that make critical infrastructures stop functioning?	Existence of lifelines	Availability of water for firefighting	Yes/no; in sufficient number/insufficient	1	4	16 water tanks within an area of 712 km^2
					Existence of a swimming pool or a water tank of more than 3 m^3 in the plot	0,5	1	YES
	Production sites	What are the factors that may lead to halting production?	Degree of dependence of production sites from lifelines	water for fighting	existence of tanks and devices for firefighting		-	Irrelevant
			Accessibility to the plant and to markets	redundancy; quality of roads; usability; expected increase in travel time	as for roads network to vulnerable areas		-	Irrelevant
			Contingency plan for na-tech	binary	yes/no		-	Irrelevant
			Business continuity plan	binary	yes/no		-	Irrelevant

Table 29: Systemic vulnerability in Ilia 2007 forest fires – infrastructures and production sites

	System	Aspect	Parameters	Criteria for assessment	Descriptors	weight	score (1=high; 5=low)	Application to Ilia case study
Social system (agents)	People/individuals	What are the factors that may reduce coping capacity during crisis?	Access to understandable information	binary	yes/no	1	3	YES, brochures for Krestena and Zacharo. However, no training program exists in schools.
			Trust in information provisers	binary	yes/no	1	2	NO
			Tenants, landowners and neighbours have been trained in fire-fighting	binary and frequency of training	yes/no; every x months/only occasionally	1	2	NO (but there exists group of volunteers)
			Voluntary fire fighers	binary; number	yes/no; number /neighborhood	1	3	YES, 10 voluntary firefighters in the area of Anc. Olympia and Krestena
			If previous yes, then Training	degree of training and means availability to volunteers	good/average/low	1	1	Low training and insufficient equipment
			Presence of impaired groups (elderly, sick persons, etc.)	binary; number and accessibility to leaving areas	yes/no; num/neighborhood and accessibility	1	2	Age structure: 19% is the elderly group
	Community and Instituions	What are the 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	1	NO
			If previous yes, Training using the contingency plan	binary; frequency of training	yes/no; every year/only occasionally	1	1	NO
			Overlapping responsiblities among agencies	degree	Low/medium/high	0,5	1	High
			Established protocols for information sharing	binary	yes/no	0,5	1	NO
			Established protocols for use of resources to manage the crisis	degree	yes/no/partial	0,5	1	NO

Table 30: Systemic vulnerability in Ilia 2007 forest fires – the social system

As far as **infrastructures** are concerned (Table 29), existence of critical lifelines for forest fires is scored 1 (due to availability of swimming pools that serve as emergency water reservoirs) and 4 (because of insufficient number of public water tanks). If we **take production** sites into consideration, systemic vulnerability cannot be assessed, due to irrelevance of all parameters for the specific area and hazard. The coping capacity of the **social system** is significantly reduced from structural impediments (Table 30). These are: low to medium efficiency in information management, formal and repeated training of locals in dealing with the hazard and, finally, population ageing. These conditions are further highlighted due to improper or even non-existent crisis management, which seems to be the overall critical inefficiency. Overlapping responsibilities among agents further deteriorates the problem.

4.4.2 Floods

The **Natural Environment system** is the first to be assessed (see

	System	Aspect	Parameters	Criteria for assessment	Descriptors	Weight	Data reliability 1 (high) - 5 (low)	Vulnerability score 1 (high) - - 5 (low)
Natural environment	*Natural ecosystems*	Are natural ecosystems fragile to the potential secondary effects of floods ?	Are crops and other agricultural productions vulnerable to contaminated water	By type of production and concentration/type of contaminant	Detailed analysis of potential contaminants sources in area	1	2	1
			Areas that may be vulnerable to secondary contamination or to rock boulders, shingle, mud deposits	Along the river and floodplains; considering dispersion mode of contaminants or material	Contaminants, rock, stones, boulders, mud, transportation processes	0,5	2	1

Table 31) and because (a) production in this region is mainly of agricultural crops and animals which depend upon land and soils that can be rapidly eroded by floods and (b) floods are likely to be high velocity debris laden, and damaging ones, systemic vulnerability is assessed as high (i.e. 1). For the **Built Environment** (Table 32) the existence of vulnerability of underground facilities in relation to flood risk is considered to be a critical factor in systemic vulnerability. However, unfortunately because no data are available to assess the degree of dependence of the region on such facilities it has not so far been feasible to assign a vulnerability score, but buildings with these facilities appear to be few. Partly because of the fire risk, emergency planning and preparedness facilities and related installations such as hospitals and medical centres are relatively well developed in the case study area. The range of public services has been planned according to assessments of the fire risk. Although the location of these facilities, particularly those relating to fire, is irrelevant to flood risk, the presence of such facilities and services in general serves to reduce the level of systemic vulnerability in the area which on the 'existence of public facilities etc.' parameter is therefore assigned a vulnerability score of 3. The lack of well-developed structural and non-structural flood risk prevention measures in most areas, and the lack of construction methods which do not take flood risk specifically into account, adds further relatively high dimensions of systemic vulnerability.

	System	Aspect	Parameters	Criteria for assessment	Descriptors	Weight	Data reliability 1 (high) - 5 (low)	Vulnerability score 1 (high) - - 5 (low)
Natural environment	*Natural ecosystems*	Are natural ecosystems fragile to the potential secondary effects of floods ?	Are crops and other agricultural productions vulnerable to contaminated water	By type of production and concentration/type of contaminant	Detailed analysis of potential contaminants sources in area	1	2	1
			Areas that may be vulnerable to secondary contamination or to rock boulders, shingle, mud deposits	Along the river and floodplains; considering dispersion mode of contaminants or material	Contaminants, rock, stones, boulders, mud, transportation processes	0,5	2	1

Table 31: Systemic vulnerability: vulnerability to losses for the natural environment – assessment at Prefecture and National scales (i.e. Ilia and Greece)

	System	Aspect	Parameters	Criteria for assessment	Descriptors	Weight	Data reliability 1 (high) - 5 (low)	Vulnerability score 1 (high) - - 5 (low)
Built environment	Exposure and vulnerability of the built environment	What are the factors that make buildings, the urban fabric and public facilities vulnerable to the losses ?	Dependence on facilities which possess underground elements such as access routes, basements, tunnels	Binary; extent	Yes/no; lengths of routes, % with underground facilities	1	5	-
			Lack of safe (high level) exit routes from underground facilities or flooded buildings	Binary; extent	Yes/no; lengths of routes, % with underground facilities	1	5	-
			Existence of public facilities: hospitals, fire brigades, emergency control rooms	Yes/no; functional capacity of such facilities	Assessment of functional potential	1	3	3
			Range of service of public facilities	Importance in potentially stricken areas	Local/regional/national facilities	0,5	5	-
			Existence of structural and non-structural flood mitigation measures	To protect key facilities and reduce losses	Yes/no; partially, almost fully	1	4	2
			Accessibility to vulnerable areas	Redundancy; quality of roads, usability; expected travel time	Yes/No	1	4	2
			Accessibility to public facilities	Redundancy; quality of roads, usability; expected travel time	low/medium/high risk	1	4	3

Table 32: Systemic vulnerability: vulnerability to losses for the built environment – assessment at Prefecture and National scales (i.e. Ilia and Greece)

	System	Aspect	Parameters	Criteria for assessment	Descriptors	Weight	Data reliability 1 (high) - 5 (low)	Vulnerability score 1 (high) - - 5 (low)
Infrastructure and production sites	Critical infrastructures	What are the factors that make critical infrastructure vulnerable (mainly lifelines) ?	Existence of lifelines	Binary	Yes/no	1	5	3
			Degree of interdependence of lifelines	Level of redundancy; binary	High redundancy; emergency devices exist/do not; autonomous capacity exists/does not	1	5	.
			Continuity plan for lifelines, individually and in a coordinated manner	Binary	Yes/no; considers all potential threats/does not	1	5	.
			Degree of dependence of critical public facilities on lifelines	Binary	Autonomous plants exist/do not; alternative resources are available or not available	1	5	.
			People and areas depending on lifelines in potentially affected areas	Numbers, area dimension	Number of customers who may be affected; geographical areas	1	4	2
			Duration of outages	Hours/days	Few hours/>24 hrs	0,5	5	.
		What are the factors that may lead to halting production ?	Degree of dependence of production site(s) on lifelines	Binary	Autonomous plants exist/do not exist; alternative resources are available/not available	1	4	3
			Transferability possibilities to other production site(s)	Binary or degree	Yes/no or none/partial/most	0,5	5	.
			Accessibility to the plant and its markets	Redundancy; quality of roads; usability; expected increase in travel time	Only 1 road/more alternatives; local/regional/state roads <2hrs/>4hrs	1	5	-
			Contingency plan for na-tech	Binary	Yes/no; considers all potential threats/does not	1	5	-
			Capacity to invest in recovery and take preventive actions	Binary or degree	Yes/no or none/partial/high	1	5	-
			Business continuity plan	Binary	Yes/no	1	5	-

Table 33: Systemic vulnerability: vulnerability to losses for infrastructures and production sites – assessment at Prefecture and National scales (i.e. Ilia and Greece)

System	Aspect	Parameters	Criteria for assessment	Descriptors	Weight	Data reliability 1 (high) - 5 (low)	Vulnerability score 1 (high) - - 5 (low)
Social systes (agents) – People/individuals	What are the factors that may reduce coping capacity during crisis ?	Access to understandable information	Binary and redundancy	Yes/no; radio and TV/special telephone number/internet	1	3	1
		Trust information providers	Binary or degree	Yes/no; good/average/low	1	5	1
		Temporary houses of low robustness	Mobile homes etc.	No. living in these	1	5	.
		Preparedness in case of event	Degree	Good/partial/low	1	5	2
		Existence of individual/community evacuation plan	Binary	Yes/no	1	4	2
		Availability of temporary shelter	Degree	Good/partial/low	1	5	.
		Availability of temporary location for patients/ill people.	Binary	Yes/no	1	5	.
		Existence of preparedness plans	Difficulties in complying with evacuation orders and in escaping	Yes/no	1	5	1
		Existence of contingency plan for threats at stake	Binary; date of last production or update	Yes/no; recent/old	1	5	1
		Training using the contingency plan	Binary; frequency of training	Yes/no; every 2 yrs/>2yrs	1	4	.
Community and institutions	What are the key factors that may hamper effective crisis management ?	Existence of large numbers of visitors/tourists	Difficulties to comply with evacuation orders and knowing what to do	Numbers of visitors/tourists	1	3	2
		Overlapping responsibilities among agencies	Degree	Low/medium/high	0,5	5	.
		Established protocol for information sharing	Binary	Yes/no	1	5	.
		Established protocol for use of resources to manage crisis	Degree	Low/medium/high	1	5	.
Economic stakeholders	Are economic stakeholders prepared to face crisis?	Capacity to run economy and respond to crises	Degree	Yes/partially/no	1	5	.
		Capacity to invest in recovery and take preventive actions	Binary or degree	Yes/no or none/partial/high	1	5	.

Table 34: Systemic vulnerability: vulnerability to losses for the social system – assessment at Prefecture and National scales (i.e. Ilia and Greece)

Where **Infrastructure and production site** systems are concerned (

System	Aspect	Parameters	Criteria for assessment	Descriptors	Weight	Data reliability 1 (high) - 5 (low)	Vulnerability score 1 (high) - - 5 (low)
Infrastructure and production sites – Critical infrastructures	What are the factors that make critical infrastructure vulnerable (mainly lifelines) ?	Existence of lifelines	Binary	Yes/no	1	5	3
		Degree of interdependence of lifelines	Level of redundancy; binary	High redundancy; emergency devices exist/do not; autonomous capacity exists/does not	1	5	.
		Continuity plan for lifelines, individually and in a coordinated manner	Binary	Yes/no; considers all potential threats/does not	1	5	.
		Degree of dependence of critical public facilities on lifelines	Binary	Autonomous plants exist/do not; alternative resources are available or not available	1	5	.
		People and areas depending on lifelines in potentially affected areas	Numbers, area dimension	Number of customers who may be affected; geographical areas	1	4	2
		Duration of outages	Hours/days	Few hours/>24 hrs	0,5	5	.
	What are the factors that may lead to halting production ?	Degree of dependence of production site(s) on lifelines	Binary	Autonomous plants exist/do not exist; alternative resources are available/not available	1	4	3

		Transferability possibilities to other production site(s)	Binary or degree	Yes/no or none/partial/most	0,5	5	.
		Accessibility to the plant and its markets	Redundancy; quality of roads; usability; expected increase in travel time	Only 1 road/more alternatives; local/regional/state roads <2hrs/>4hrs	1	5	-
		Contingency plan for na-tech	Binary	Yes/no; considers all potential threats/does not	1	5	-
		Capacity to invest in recovery and take preventive actions	Binary or degree	Yes/no or none/partial/high	1	5	-
		Business continuity plan	Binary	Yes/no	1	5	-

Table 33), again unfortunately there is a lack of data relating to critical infrastructures which represent an important gap in flood risk knowledge in the region which requires addressing – this in itself is a vulnerability. Vulnerability of lifelines and the dependence of agricultural production facilities on such lifelines is likely to be important and is scored at relatively high (2) and medium (3) levels of systemic vulnerability. Crops produced in the area are perishable and disruption of transport to markets will have adverse economic consequences. Figure 23 shows the road network in relation to rivers and settlements. Although it is impossible to identify in detail at this scale the precise relationship of rivers and likely flood risk areas to road routes and locations, it is apparent from Figure 23 that the road system uses many river bridging points (which are potentially physically vulnerable flood damage sites) and has comparatively few exit and entry routes to the south and south-east of the region across the eastern mountainous area which is the main transportation gateway to more populous markets in Greece.

Systemic vulnerability of the **Social system** is generally scored as high (1) or relatively high (2) (

	System	Aspect	Parameters	Criteria for assessment	Descriptors	Weight	Data reliability 1 (high) - 5 (low)	Vulnerability score 1 (high) - - 5 (low)
Social systes (agents)	People/individuals	What are the factors that may reduce coping capacity during crisis ?	Access to understandable information	Binary and redundancy	Yes/no; radio and TV/special telephone number/internet	1	3	1
			Trust information providers	Binary or degree	Yes/no; good/average/low	1	5	1
			Temporary houses of low robustness	Mobile homes etc.	No. living in these	1	5	.
			Preparedness in case of event	Degree	Good/partial/low	1	5	2
			Existence of individual/community evacuation plan	Binary	Yes/no	1	4	2
			Availability of temporary shelter	Degree	Good/partial/low	1	5	.
			Availability of temporary location for patients/ill people.	Binary	Yes/no	1	5	.
			Existence of preparedness plans	Difficulties in complying with evacuation orders and in escaping	Yes/no	1	5	1
			Existence of contingency plan for threats at stake	Binary; date of last production or update	Yes/no; recent/old	1	5	1
			Training using the contingency plan	Binary; frequency of training	Yes/no; every 2 yrs/>2yrs	1	4	.
	Community and institutions	What are the key factors that may hamper effective crisis management ?	Existence of large numbers of visitors/tourists	Difficulties to comply with evacuation orders and knowing what to do	Numbers of visitors/tourists	1	3	2
			Overlapping responsibilities among agencies	Degree	Low/medium/high	0,5	5	.
			Established protocol for information sharing	Binary	Yes/no	1	5	.
			Established protocol for use of resources to manage crisis	Degree	Low/medium/high	1	5	.
	Economic stakeholders	Are economic stakeholders prepared to face crisis?	Capacity to run economy and respond to crises	Degree	Yes/partially/no	1	5	.
			Capacity to invest in recovery and take preventive actions	Binary or degree	Yes/no or none/partial/high	1	5	.

Table 34). A range of factors are likely to reduce coping capacity during a flood crisis in the region – particularly if flooding is severe and region wide (i.e. extreme events occurring simultaneously throughout the river systems). Public access to flood risk information is poor; public trust in governmental agencies is medium to low and there is a general tendency to blame the government in crises; flood preparedness is low; and flood evacuation plans do not exist in most cases. It is likely therefore that the social system (i.e. people and individuals) will therefore be severely affected in a significant flood emergency of the kind outlined above. The potential presence of a large number of tourists during a flood emergency will only serve to exacerbate systemic vulnerability. Institutional factors often play an important part in crisis management but unfortunately there is currently a lack of suitable information on these to enable vulnerability scoring to be undertaken. The same is so for economic stakeholders.

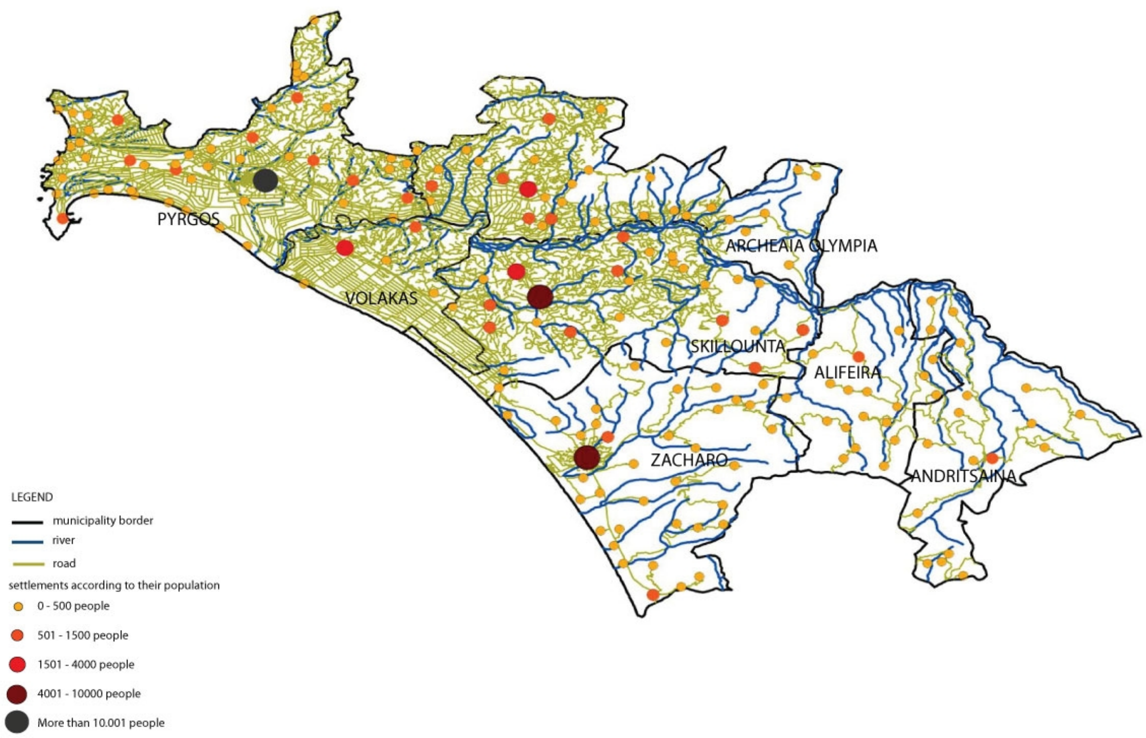

Figure 23: The general relationship between rivers and road networks in the study area

4.5 Resilience

4.5.1 Forest fires

Resilience of the **natural environment**, i.e. its ability to recover from damages caused by the 2007 mega-fires, is low to medium; therefore vulnerability of the system is given a high to medium score (Table 35). Burnt forest area recovery is highly dependent on fire interval and vegetation re-growth, therefore one has to wait a bit longer in order to be able to make a sound appraisal (nonetheless the latter is given a 2 score on the basis of empirical assumptions). Use of endemic species following a specific study was only been made in the Ancient Olympia archaeological site, while lack of more thorough data, as well as time and budget constraints, do not allow for developing an analysis of satellite pictures, a task that forms a basic technique for regeneration estimations.

	System	Aspect	Parameters	Criteria for assessment	Descriptors	weight	score (1=high; 5=low)	Application to Ilia case study
Natural environment	Natural ecosystems	Are natural environments hit by the event able to recover from damages to species and ecosystems?	Recovery capacity of burnt areas	extent of damage to vegetation	Resprouting likely/unlikely	1	-	For this parameters one would need to evaluate fire intensities. At present this is rather not feasible.
			Fire interval	Elapsed time between two consecutive fires (Delgado etal 2002 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 ecossystems. They measure plant cover recovery 38 months after the second fire).	Days	1	1 fire in >4000; 2 fires every 3000/4000 days; 3 fires every 3000/4000 days; 4 fires in <2000 days	Despite the scattering, studies present a linear regression between fire interval and vegetation resilience. The interval above 4000 days shows a good recovery, below 2000 days vegetation recovered in average only up to half of its previous resilience. The threshold of resilience seems to be around the 11 year mark.
			Fire recovery	Post fire vegetation re-growth	South facing slopes/North facing slopes	0,5	2	A post vegetation fire study took place in Mount Carmel, Israel. Unlike the study from Delgado, the recovery of vegetation was seen to occur better in north face slopes in contrast with south facing slopes. This seems to be a dominant assumption on the fire community. The choice for 4 and 2 vulnerability scores reflect that the difference is not very extreme, as highlighted by the study.
			burnt areas management	logging procedures	immediate logging after fire/delayed logging	0,5	3	
				plants used for reforestation	use of endemic species for reforestation/use of fast growing vegetation	1	2	This parameter is very country specific. In theory, salvage harvesting can indeed lead to decreased regeneration after a fire, but harvesting can also lead to lower fuel loads at the stand and therefore make the fire less intense. One may instead focus on post burn fire policies. How is the reforestation of burnt areas planned? Are endemic species used or agents relly on fast growing vegetation (in general less resilient and more prone to fires)? In Ancient Olympia archaelogical site a plan was implemented that allowed for use of fire-tolerant and historic vegetation.
			availability of maps and pictures to document regeneration	binary	yes/no	0,5	-	Usually studies make use of satellite pictures to document changes in post-fire vegetation. These images are ussualy free available on MODIS web site, but such a task is not feasible at present.

Table 35: Resilience of the natural environment system in Ilia 2007 forest fires

If we turn to the **built environment** to assess its ability for recovery (Table 36), we see that the structure of land ownership is actually an obstacle in applying basic mitigation measures that lead to recovery, such as vegetation clearance in fragile zones at the small scale. But what is more important is the fact that both sharing among stakeholders and integration of physical reconstruction with healing processes are assessed as rather low. The same applies for the existence and strength of norms that lower systemic vulnerability to a significant extent, like these that deal with the creation of new –or renovation of existing – building units within burnt areas, despite the norms that are set by the legislation.

	System	Aspect	Parameters	Criteria for assessment	Descriptors	weight	score (1=high; 5=low)	Application to Ilia case study
Built environment	*Exposure and vulnerability of built environment*	Is the urban fabric/built environment able to recover reducing pre-event vulnerability?	Existence of plans and provisions to encourage mitigation in buildings and surrounding zones	binary	yes/no	1	2	Difficulties in vegetation clearance around buildings due to ownership obstacles
			Creation of emergency access	binary	yes/no	1	1	No
			Level of sharing among stakeholders of reconstruction plans	degree	low/average/high	1	2	Low
			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	2	Low
			Existence and strength of norms prohibiting building in burnt areas	binary; degree of compliance/inspection capability	yes/no; low/high	1	2	Laws exist but their enforcement is generally poor; but the 2007 fires is different for their severtiy and therefore more compliance can be observed

Table 36: Resilience of the built environment system in Ilia 2007 forest fires

When **infrastructures and production sites** are taken into consideration, the overall system is slightly less vulnerable, yet its score is again medium (see Table 37). This is because there are indeed tools for the recovery of critical infrastructure, such as survey devices and sparse materials / personnel for fast repairs, but there are important issues of ad-hoc initiatives and low quality that do not allow for their full exploitation. In addition, systemic vulnerability is augmented due to the economic profile of the locality: reliance on tourism and agriculture means that economic resources –and therefore the local economy – are quite exposed to the hazard.

This is also pictured in the assessment of the **social system** (Table 38). First of all, availability of private funds in the form of donors cannot balance the lack of economic means for tackling structural impediments. This is why the social system at its smallest scale (individuals) exhibit a high level of vulnerability. But there are also other important structural deficiencies. The aging population, the negative growth change of the population as a total, and the dependence on unskilled labour mainly in agriculture constitute important barriers to the resilience of the community (though other features like low criminality rate and limited social conflicts help increase resilience). Luck of accountability and trust in institutions is reported as a significant problem, and so are the capabilities of local stakeholders to act in such a way as to economically reinforce resilience.

	System	Aspect	Parameters	Criteria for assessment	Descriptors	weight	score (1=high; 5=low)	Application to Ilia case study
Infrastructure and production sites	Critical infrastructures	Are there tools to recover critical infrastructures rapidly and at low costs?	Water system for firefighting	level of improvement after disaster	low/high	1	3	High
			In site devices for quick survey of damaged parts	binary	yes/no	1	2	Sporadic initiatives
			Availability of spare materials for fast repairs	binary	yes/no	1	3	YES (logs to protect from floods and soil erosion)
			Availability of personnel for repairs	binary	yes/no	1	3	Yes (mostly unskilled and foreign labour forces)
			Existence of protocols to proceed with repairs requiring inter-lifelines interventions	binary	yes/no	0,5	1	NO
	Economic activities		Relevance of the area as a tourist attraction	degree	low/average/high	1	4	Yes (high)
			Activities depending on the existence of woods	binary	yes/no	0,5	2	No (only in few settlements, like in the Smema community, where exploitment of forests for charcoal production stopped after the fires). Large agricultural losses
			Economic sectors	Diversified or concentrated on few sectors	Few/many different economic sectors in the area	1	2	Tourism and agriculture are the only sectors, both severly affected by the fires

Table 37: Resilience of infrastructures and production sites in Ilia 2007 forest fires

	System	Aspect	Parameters	Criteria for assessment	Descriptors	weight	score (1=high; 5=low)	Application to Ilia case study
Social system (agents)	People/individuals	Are people in the position to be resilient in the face of a catastrophe?	Availability of psychological support for adults and children	degree	yes/no/making part of ordinary practices	1	1	Bsically NO
			Availability of private resources for recovery	degree	yes/no	1	4	Availability of private donors for reconstruction
			Availability of private resources for recovery	Income/per capita	high/average/low	1	1	This is one of the poorest prefectures in Greece
			Access to insurance	binary; coverage	yes/no; percentage of coverage	0,5	1	NO
	Community	Is the affected community resilient to the consequences of a catastrophe?	Age structure	Aging population; low fertility rates	indexes	1	2	Low to medium (see map)
			Local condition of aged population	autonomous/not autonomous; relatively healthy/not healthy	autonomous/not autonomous; relatively/not healthy	1	-	No data
			Employment rate	degree	high/medium/low	1	3	Medium
			Annual population growth rate (over the last five years)	degree	high/medium/low/negative	1	2	Negative (annual population change -natural movement- index is -4,4) (2005).
			Immigration index	degree	high/medium/low/negative	1	2	Medium (average). 6,2% of Ilia population are foreign immigrants (7,3% for Greece). 60% of Ilia immigrants are employed in agricultural sector.
			Social networking	degree	high/medium/low/negative	1	4	High
			Criminality rate	degree	high/medium/low	0,5	4	Low
			Conflict among social/ethnic groups	degree	high/medium/low	0,5	3	Medium
	Institutions	Are institutions in charge of reconstruction transparent, reliable and trustable?	Trust in institution	degree	high/medium/low (from sociological surveys when available)	1	2	Low
			Transparency in funds allocation	Existance of public information and independent control mechanisms	yes/no	1	2	NO
			Long term vision	Existance of strategic development/land use plans	yes/no	1	1	NO
	omic stak ehol	Are economic stakeholders	Insurance coverage	binary; coverage	Yes/no;percentage	1	1	NO

capable/wishing to reinvest in affected areas?	Dependance of economic actors on loss of environmental goods	Prevalent tourist acitvity; agricultural activity	percentage	1	1	High

Table 38: Resilience of the social system in Ilia 2007 forest fires

4.5.2 Floods

This matrix is about the degree to which resilience is built into or can be recognised as part of the natural and built environment and other systems being considered. Where resilience is part of a system, this is recognised by a parameter vulnerability score ranging from 1-5 where 1 = high vulnerability (i.e. low resilience) and 5 = low vulnerability (i.e. high resilience).

We examine a number of parameters in the **natural systems** section of this matrix (see

System		Aspect	Parameters	Criteria for assessment	Descriptors	Weight	Data reliability 1 (high) - 5 (low)	Vulnerability score 1 (high) - - 5 (low)
Natural environment	*Natural ecosystems*	Are natural environments struck by the event able to recover from damages to species and ecosystems ?	Resilience of crops and other agricultural production to floods	Depends on depth and duration of flood water and its velocity, water contamination, debris load and type of crops/production	Resilient/partially resilient/non-resilient	1	3	1
		Are natural environments and ecosystems able to recover from mitigation with neg. environmental impact ?	Water quality in rivers	Binary	Remediation required/not required	1	5	3
		Structural measures	Flood retention areas	Binary/legal provisions	Can be accommodated/cannot; legal impediments to taking from development	0,5	4	4
			Levees	Binray/funding	Can/cannot be built, funding mechanisms in reconstr.programmes	1	5	.
			Demountable flood defences	Applicable/not applicable; available/not available	Yes/no; yes/no	-	5	-

Table 39) including ones relating to resilience of crops, the coping capacity of natural systems to deal with water quality deterioration associated with floods, and structural flood protection measures of various kinds. For reasons already explained above, we assess crops of this region to be probably highly vulnerable (i.e. scored as 1) to the types of damaging floods which are characteristic of the area. There are insufficient data to assess the water quality issues arising from floods but in theory at least high sediment and rock content of floodwaters is likely to be characteristic leading to some lack of resilience or level of vulnerability (assessed as 3). Flood retention basins are not likely to be widely applicable as a flood control measure in this region and there is no information on the use of demountable flood defences which also may have low applicability here.

System		Aspect	Parameters	Criteria for assessment	Descriptors	Weight	Data reliability 1 (high) - 5 (low)	Vulnerability score 1 (high) - - 5 (low)
Natural environment	*Natural ecosystems*	Are natural environments struck by the event able to recover from damages to species and ecosystems ?	Resilience of crops and other agricultural production to floods	Depends on depth and duration of flood water and its velocity, water contamination, debris load and type of crops/production	Resilient/partially resilient/non-resilient	1	3	1

	Are natural environments and ecosystems able to recover from mitigation with neg. environmental impact ?	Water quality in rivers	Binary	Remediation required/not required	1	5	3
	Structural measures	Flood retention areas	Binary/legal provisions	Can be accommodated/cannot; legal impediments to taking from development	0,5	4	4
		Levees	Binray/funding	Can/cannot be built, funding mechanisms in reconstr.programmes	1	5	.
		Demountable flood defences	Applicable/not applicable; available/not available	Yes/no; yes/no	-	5	-

Table 39: Resilience: response capacity in the longer-term – assessment at Prefecture and National scale (i.e. Ilia and Greece): Natural environment

Generally, resilience in the **Built Environment** system is assessed as low or fairly low (i.e. high to medium vulnerability) (

	System	Aspect	Parameters	Criteria for assessment	Descriptors	Weight	Data reliability 1 (high) - 5 (low)	Vulnerability score 1 (high) - - 5 (low)
Built environment	Exposure and vulnerability of the built environment	Is the urban fabric/built environment able to recover reducing pre-event vulnerability ?	New development and refurbishment programmes include risk prevention on an ordinary basis	Degree or extent	Yes/partially/no	1	5	1
			Detailed flood damage analysis	Degree and scale of damage	Yes/partially/no; resolution	1	5	.
			Building codes address flood risk for new construction and retrofitting	Degree; compliance	Yes/partially/no	1	3	1
			Availability of partial relocation programmes during reconstruction for the most critical situations.	Binary	Yes/no	1	4	3
			Ability to incorporate recovery/resilience measures in future urban redevelopment plans	Binary/degree	Yes/no; none/partial/high	1	5	1
			Level of financial sharing among stakeholders in the reconstruction phase	Binary	Low/medium/high risk	1	4	3
			Relevance of potentially affected settlements in geographic/economic terms	Degree of relevance	Centre/peripheral	0,5	3	3

Table 40). Currently, flood risk reduction is not systematically or ordinarily built in to the planning of new development (the vulnerability score is therefore 1). The management of the built environment is not well attuned to the flood risk in the case study area: hence although no data are available there appears to be no flood damage analysis relating to building which allows resilience to be measured and subsequently increased through damage reduction measures. The application of building codes and regulations is not a particular strength of the planning and building system in Greece and there is little resilience built in as a consequence (i.e. high vulnerability, 1). Although considered for earthquake and landslide hazard prevention, relocation of properties to make them flood free is not considered but in reality would only be considered in rare occasions because of the relatively high cost (vulnerability = 3).

	System	Aspect	Parameters	Criteria for assessment	Descriptors	Weight	Data reliability 1 (high) - 5 (low)	Vulnerability score 1 (high) - - 5 (low)
Built environment	Exposure and vulnerability of the built	Is the urban fabric/built environment able to recover reducing pre-event vulnerability ?	New development and refurbishment programmes include risk prevention on an ordinary basis	Degree or extent	Yes/partially/no	1	5	1
			Detailed flood damage analysis	Degree and scale of damage	Yes/partially/no; resolution	1	5	.

		Building codes address flood risk for new construction and retrofitting	Degree; compliance	Yes/partially/no	1	3	1
		Availability of partial relocation programmes during reconstruction for the most critical situations.	Binary	Yes/no	1	4	3
		Ability to incorporate recovery/resilience measures in future urban redevelopment plans	Binary/degree	Yes/no; none/partial/high	1	5	1
		Level of financial sharing among stakeholders in the reconstruction phase	Binary	Low/medium/high risk	1	4	3
		Relevance of potentially affected settlements in geographic/economic terms	Degree of relevance	Centre/peripheral	0,5	3	3

Table 40: Resilience: response capacity in the longer-term – assessment at Prefecture and National scale (i.e. Ilia and Greece): Built environment

System	Aspect	Parameters	Criteria for assessment	Descriptors	Weight	Data reliability 1 (high) - 5 (low)	Vulnerability score 1 (high) - - 5 (low)
Infrastrucuture and production sites	*Critical infrastructures*	Are there tools to recover official infrastructures rapidly and at low costs ?					
		Computerised mapping systems of infrastructures	Binary	Yes/no	1	5	2
		In-site devices for rapid survey of damaged components	Binary	Yes/no	0,5	5	2
		Availability of spare parts for rapid repairs	Binary; time required to transport spares to hazard zone	Yes/no; 1 day; >1 day	1	4	.
		Availability of personnel for repairs	Binary; nos. of technicians available with respect to potential need	Yes/no; on site/distant; proportional/not proportional to need	1	5	3
		Existence of protocols to proceed with repairs requiring inter-lifelines interventions	Degree; number of available technicians with respect to expected need	Yes/partially/no; protocols among all companies of coordinated by authorities/limited agreements	0,5	5	.
		Temporary transferability of production in case of need	Binary	Applicable/not aplicable	1	4	5
		Existence of funds for rapid repairs	Binary	Yes/no	1	5	.
		Existence of inspection and guiding personnel for correct repairs	Binary	Yes/no; forecasted in the recovery plans	0,5	5	2
		Economic sectors	Diversified or concentrated on few sectors	Few/many different economic sectors in the area	1	2	`

Table 41: Resilience: response capacity in the longer-term – assessment at Prefecture and National scale (i.e. Ilia and Greece): Infrastructure and production sites

As far as the **Infrastructure and production site** system (

System	Aspect	Parameters	Criteria for assessment	Descriptors	Weight	Data reliability 1 (high) - 5 (low)	Vulnerability score 1 (high) - - 5 (low)
Infrastrucuture and production sites	*Critical infrastructures*	Are there tools to recover official infrastructures rapidly and at low costs ?					
		Computerised mapping systems of infrastructures	Binary	Yes/no	1	5	2
		In-site devices for rapid survey of damaged components	Binary	Yes/no	0,5	5	2
		Availability of spare parts for rapid repairs	Binary; time required to transport spares to hazard zone	Yes/no; 1 day; >1 day	1	4	.
		Availability of personnel for repairs	Binary; nos. of technicians available with respect to potential need	Yes/no; on site/distant; proportional/not proportional to need	1	5	3
		Existence of protocols to proceed with repairs requiring inter-lifelines interventions	Degree; number of available technicians with respect to expected need	Yes/partially/no; protocols among all companies of coordinated by authorities/limited agreements	0,5	5	.

		Temporary transferability of production in case of need	Binary	Applicable/not aplicable	1	4	5
		Existence of funds for rapid repairs	Binary	Yes/no	1	5	.
		Existence of inspection and guiding personnel for correct repairs	Binary	Yes/no; forecasted in the recovery plans	0,5	5	2
		Economic sectors	Diversified or concentrated on few sectors	Few/many different economic sectors in the area	1	2	`

Table 41) is concerned available data on critical infrastructure, especially in relation to flood risk zones, are generally lacking hampering the assessment. Mapping of infrastructure in relation to flood risk is underdeveloped and this leads to a relatively high vulnerability score (i.e. 2); availability of devices for assessing damage appear not to be well developed and there may be a shortage of highly skilled technicians in the labour market to cope with disruptions and breakdowns. Because the economy is not well diversified infrastructure losses could affect the few sectors present in a focused manner leading to serious knock-on effects on the businesses of the region.

Resilience in the **Social system** (

	System	Aspect	Parameters	Criteria for assessment	Descriptors	Weight	Data reliability 1 (high) - 5 (low)	Vulnerability score 1 (high) - - 5 (low)
Social systems (agents)	*People/individuals*	Are people in the position to be resilient in the face of a catastrophe ?	Availability of psychological support for adults and children	Binary	Yes/no; making part of ordinary practices/exceptional	0,5	5	4
			Availability of physical support for those with special needs	Binary; degree of support	Yes/no; good/fair/poor	1	5	2
			Level of skills and capacity to learn and adapt	Qualitative judgement	Low/medium/high	1	5	2
			Availability of private resources to resettle/repair e.g. reserves	Binary; level of support	Yes/no; low/medium/high	0,5	3	2
			Access to public relief funds and public advice	Binary; level of support	Yes/no; low/medium/high	1	3	3
		Is the affected community resilient to the consequences of a catastrophe ?	Access to insurance	Binary; % of coverage	Yes/no; % without insurance	1	3	2
			Age structure	Age groups and fertility	Aging population; low fertility rates	0,5	5	5
			Local condition of aged population	% of autonomous and healthy population	Autonomous/not autonomous; relatively healthy/not healthy; nos. with disabilities	0,5	5	.
			Employment rate	Degree	High/medium/low	1	5	2
			Annual population growth (last 5 yrs)	Trend	High/medium/low/negative	-	2	-
			Immigration index	New immigrants/immigrants	High/medium/low/negative	0,5	5	2
			Levels of social cohesion and integration	Qualitative judgement	High/medium/low	1	5	3
			Social networking and social capital	Qualitative judgement	Low/medium/high	1	5	3
			Conflict among social/ethnic groups	Degree	Low/medium/high	-	5	.
			Criminalilty rate	Degree	Low/medium/high	-	5	.
	Institutions	Are institutions in charge of reconstruction transparent, reliable and trustworthy ?	Degree of trust in institutions by at risk public	Degree	low/medium/high (from social surveys when available)	1	5	1
			Transparency in funds allocation	Binary	Yes/no; existence of public information and independent control mechanisms	1	5	2
	Economic stakeholders	Are economic stakeholders capable/willing to reinvest in affected areas ?	Long term vision	Existence of strategic development/land use plans	Yes/no; only formal	1	4	3
			Insurance coverage for direct damage and consequential loss	Binary; % coverage	Yes/no' % without insurance	1	3	2
			Dependence of economic actors on loss of environmental goods	Prevalent tourist activity, agricultural activity	Percentage	1	3	2
			Access and information about funds	Degree	High/medium/low	1	5	2

		for reconstruction					
		Degree of diversification and capacity to spread risks	Degree	High/medium/low	1	5	2

Table 42) can reduce the impact of hazardous events such as floods but in this case study area reduction of vulnerability is likely to be limited. Generally, the social system exhibits a relatively high level of vulnerability (i.e. relatively low resilience). This is a predominantly rural and remote area in which communication can be difficult. Availability of social support for those with special needs is limited (vulnerability score of 2). Ilia is characterised by relatively low levels of education and capacity to learn and to adapt, and mean levels of income are low in the case study area leading to relatively low resilience (i.e. relatively high vulnerability). Insurance coverage is low. Unemployment is relatively high; immigration (usually associated initially with low incomes and social deprivation) is a significant factor in the South. Social cohesion is high at the domestic level providing a source of resilience but immigrants are not well integrated. However, private benefactors are at work in the region (for example funding the reconstruction of some villages destroyed recently by fire) and this factor increases resilience potential to some degree. Trust in authority is low (i.e. resilience on this parameter is low) and transparency in fund distribution is said to be questionable. There is no culture of long term planning although a special (natural assets) protection zone exists in the area but currently has no relation to resilience in terms of flood risk, although it could do in future. In terms of economic stakeholders and their willingness to reinvest in the area following a flood disaster, resilience is assessed to be rather low. For example access to funds for reconstruction is assessed to be hampered by lack of information.

	System	Aspect	Parameters	Criteria for assessment	Descriptors	Weight	Data reliability 1 (high) - 5 (low)	Vulnerability score 1 (high) - - 5 (low)
Social systems (agents)	People/individuals	Are people in the position to be resilient in the face of a catastrophe ?	Availability of psychological support for adults and children	Binary	Yes/no; making part of ordinary practices/exceptional	0,5	5	4
			Availability of physical support for those with special needs	Binary; degree of support	Yes/no; good/fair/poor	1	5	2
			Level of skills and capacity to learn and adapt	Qualitative judgement	Low/medium/high	1	5	2
			Availability of private resources to resettle/repair e.g. reserves	Binary; level of support	Yes/no; low/medium/high	0,5	3	2
			Access to public relief funds and public advice	Binary; level of support	Yes/no; low/medium/high	1	3	3
		Is the affected community resilient to the consequences of a catastrophe ?	Access to insurance	Binary; % of coverage	Yes/no; % without insurance	1	3	2
			Age structure	Age groups and fertility	Aging population; low fertility rates	0,5	5	5
			Local condition of aged population	% of autonomous and healthy population	Autonomous/not autonomous; relatively healthy/not healthy; nos. with disabilities	0,5	5	.
			Employment rate	Degree	High/medium/low	1	5	2
			Annual population growth (last 5 yrs)	Trend	High/medium/low/negative	-	2	-
			Immigration index	New immigrants/immigrants	High/medium/low/negative	0,5	5	2
			Levels of social cohesion and integration	Qualitative judgement	High/medium/low	1	5	3
			Social networking and social capital	Qualitative judgement	Low/medium/high	1	5	3
			Conflict among social/ethnic groups	Degree	Low/medium/high	-	5	.
			Criminalilty rate	Degree	Low/medium/high	-	5	.
	Institutions	Are institutions in charge of reconstruction transparent, reliable	Degree of trust in institutions by at risk public	Degree	low/medium/high (from social surveys when available)	1	5	1

	and trustworthy ?	Transparency in funds allocation	Binary	Yes/no; existence of public information and independent control mechanisms	1	5	2
Economic stakeholders	Are economic stakeholders capable/willing to reinvest in affected areas ?	Long term vision	Existence of strategic development/land use plans	Yes/no; only formal	1	4	3
		Insurance coverage for direct damage and consequential loss	Binary; % coverage	Yes/no' % without insurance	1	3	2
		Dependence of economic actors on loss of environmental goods	Prevalent tourist activity, agricultural activity	Percentage	1	3	2
		Access and information about funds for reconstruction	Degree	High/medium/low	1	5	2
		Degree of diversification and capacity to spread risks	Degree	High/medium/low	1	5	2

Table 42: Resilience: response capacity in the longer-term – assessment at Prefecture and National scale (i.e. Ilia and Greece): Social systems

5 Weaknesses and strengths of the Ensure framework

The application of the ENSURE framework to the case of three different types of hazards in the Ilia Prefecture has been a challenging task. Despite variations in the way that each hazard has been addressed, our common empirical exercise has helped identify a number of advantages of the methodology which has been the object of previous work packages, as well as a number of limiting issues where further improvements are required. Nonetheless, we believe that the current state of knowledge advancement that has been achieved via the Ilia case study makes an important step towards the rethinking of theoretically informed empirical research. In the following paragraphs, the aim is to highlight key issues that have been concluded from the case study. These issues refer to methodology, data availability and quality, scoring and weighting, context and scale.

Methodological aspects

The ENSURE methodology represents a comprehensive assessment of vulnerability, incorporating –as it does– 4 types of inter-related vulnerability, a consistent set of systems and a large range of parameters. It is possible, using such a methodology, to form a comprehensive view of vulnerability to different types of hazards in a particular, multi-hazard area. The methodology captures parameters relevant to various spatial scales and administrative levels. Its application might lead to more efficient ways of carrying out trans-boundary policies for coping with extreme events.

One of the main advantages of the EUNSURE methodology is that it may be used to formulate assessment ranging from a rapid, desk-based, partially quantitative/partially qualitative assessment of vulnerability through to a fully analytical and research based assessment employing a larger range of quantitative data (mixed with some qualitative data). This potential versatility is considered as an extremely useful quality given that it allows preliminary, screening assessments to be made which may then be followed up by more detailed and penetrating assessments as necessary.

Another advantage of the methodology is that it is characterized by transparency of the assessment process. The assumptions, simplification, limits and uncertainties of the method are explicitly declared (see how this is dealt with in all matrices presented above). In addition, the methodology is flexible enough to enable future developments in research and practice that can be incorporated without making significant changes in the whole structure of the method; and it also supports advancements in designing precautionary measures.

We also have to note that integration and synthesis of the distinct groups of matrices which correspond to the selected hazards (i.e. forest fires, floods, earthquakes) has not been made possible, because the sub-areas of Ilia are different, though overlapping. This is hardly surprising and should not be considered as a shortcoming, since it has been the inevitable outcome of diversified exposures. Furthermore, the methodology has been proved to be ideal for comparing vulnerability of the four carrying systems (the natural, the building, the infrastructures and the social) at a specific stage, as well as for comparing vulnerability of a specific system at the distinct stages. However it does not offer a formula for integrated assessment of vulnerability of all systems during a full disaster cycle, a task that can be set to be a future, big challenge.

Availability and quality of data

The framework requires a significant amount of data when the operator chooses to go beyond the desk-top based approach. Such a task can be problematic in terms of time and cost. However, it has to be recognised that a penetrating analysis of vulnerability is almost bound to require a significant amount of data.

Such a requirement is accompanied with two limitations. First, data may not exist to allow a parameter to be assessed and therefore a data gap may emerge in such cases. Non-existence of data may be related to limited availability of data according to the targeted geographical scale. It may also be related to significant time laps due to source of data (i.e. censuses providing data in 10-years periods). Second, in many instances the parameters at hand are of a synthetic nature and have been built on specific data combinations. Therefore, possible data gaps may weaken the overall elaboration of such parameters.

But, despite these limitations, what is important here is that the methodology allows the operator to record, and then use when assessing vulnerability, the quality of the data used to score parameters. This feature also allows areas where data quality needs improving to be highlighted for further action. In this respect, limited availability and/or synthesis of data can be a strength in that it allows for data improvement and better targeting in subsequent rounds of vulnerability assessment.

Scoring and weighting

The scoring and weighting system is a core aspect of the framework. Given the current state of methodological advancement, different scoring alternatives have been explored in dealing with the various types of hazards. Such a variety allows for a much needed flexibility when it comes to the complex pragmatics of empirical assessment.

On the other hand, lack of harmonization, as well as the inconsistencies of synthesizing quantitative and qualitative parameters in different ways, exhibits some limitations. At present the vulnerability scores are crude and it is may be unclear how overall vulnerability can be measured when using different scores and types of scores. Each weight and score also requires further definition to ensure consistent use across operators and among different types of hazards. Moreover, it may sometimes be that one indicator is the combination of several other parameters, which can lead to some difficulties if the system is not well defined or data availability or quality is low. One last problem has to do with the fact that, in several cases, vulnerability values varied enormously between the pre- and post-disaster stage. Therefore there is still room for further experimentation regarding the theoretical aspects of our methodology.

Specificity of context and geographical scale

The framework has helped to identify how parameters may differ not just for different hazards but also within different European contexts. For example, parameters such as lack of safe exits routes from underground facilities or flooded buildings were found to be largely irrelevant for Ilia in the case of flash floods. Thus many of the parameters identified for floods in different European contexts –e.g. urban areas in the UK and Germany– proved to be irrelevant in the case of rural Ilia. Such a conclusion reinforces the fact that floods (and alternatively any hazard), their impacts and institutional arrangements for dealing with them are context specific.

Another issue has to do with geographical scale. Assessments may be conducted at a variety of scales and care needs to be exercised when comparing assessments among different scales. This problem has been highlighted in the matrices just as there have been spatial –as well as temporal– variations of parameter values and vulnerability scores. Each single matrix features parameters which are different in their scale of reference. Some parameters are homogenous for the whole area under consideration (eg. institutional parameters); other ones diverse enormously from one building to another, from one village to another etc. The scale problem has been adequately dealt with in each hazard case, and in all cases a change in scale was explicitly made clear. On the other hand, the scale problem can be said to form one of the specific issues for which further steps combining methodology and theory are still to be made.

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