European Commission

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Overview of Disaster Risks that the EU faces

Internal assessment based on JRC databases

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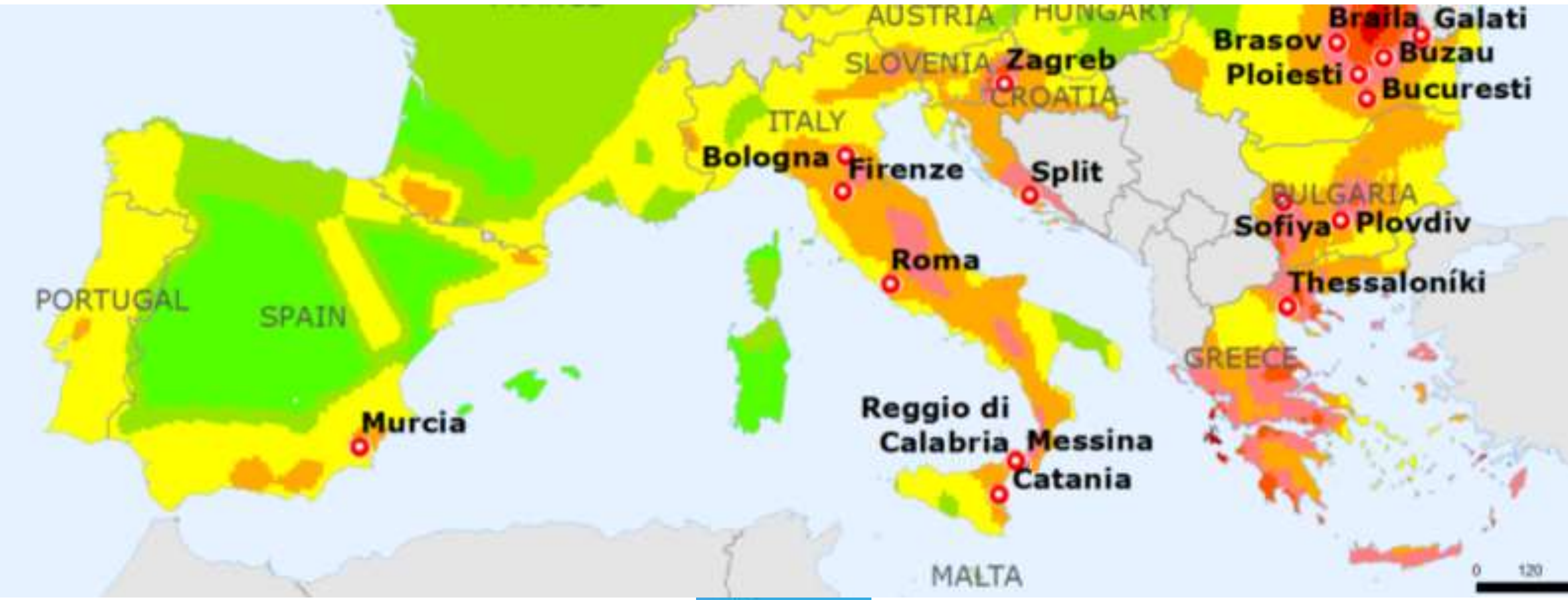

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1 Introduction

In 2011, the Council asked the Commission to develop an overview of the risks the EU may face in the future based on national risk assessments. The overview will focus primarily on risks which are 'shared'; i.e. those with likely cross-border impacts, or those on a larger scale where impacts would be experienced by more than one MS. By doing so, the overview will help to determine areas for cooperation between MS on disaster prevention and preparedness. It will feed into planning for civil protection response, and there will be lessons for other policy areas such as climate adaptation. It is already becoming clear that the initial overview will also identify areas requiring additional research and highlight where there is a need for improved data availability.

While the intention is to look, at a later stage, also at emerging risks with a high impact/low probability nature, the initial overview focuses on the next five-year period. This time period allows a more reliable assessment of the probability of hazards occurring, and corresponds approximately to timescales for funding potential actions addressing risks. Another area to be addressed in future is that of multi-hazard, where unrelated risks occur simultaneously or a cascade of disasters arises.

At the end of 2012, the Commission has received contributions on national risk assessments from 12 out of 32 countries participating in the Community Civil Protection Mechanism (Participating States): Czech Republic, Denmark, Estonia, Germany, Hungary, Italy, Netherlands, Norway, Poland, Slovenia, Sweden and UK. Some are complete or summary assessments while others such as Denmark, Germany, Hungary and Sweden have sent information on the process to develop risk assessment and lists of hazards to be assessed. More risk assessments are being prepared, including a regional project covering ten Baltic countries due to report in June 2013. Comparability of data is an issue as the national approaches and methodologies differ; for example, while some countries have weighted the risks, others have not (yet) ranked them according to probability and/or impact, instead choosing to concentrate on a list of possible risks. The EU overview will present results as much as possible in the form of risk matrices, mapping both likelihood and impact of a risk. Some Participating States such as Poland, UK, Netherlands, Slovenia and Norway already present their national risk assessments in this form.

A first analysis of national risk assessments received so far show that the most wide-spread risks (cited by 75-80% of respondents) are floods and extreme weather events, followed by pandemics, terrorist attacks and cyber-attacks (2/3 of respondents). Other wide-spread risks (50-60% of respondents) are wild or forest fires; Chemical, Biological or Nuclear contamination and industrial accidents. Lower-ranking risks (>25-50%) are loss of critical infrastructure such as transport, energy or water networks; earthquakes; livestock epidemics; nuclear accidents and civil unrest/polarisation of society. Risks that concern 25% or fewer of the countries responding so far are marine pollution and oil spills, volcanic eruptions, landslides and transport accidents.

To complement the material sent by Participating States, ECHO.A.3 visited the Joint Research Centre (JRC) on 23 October 2012 to discuss with relevant Units on available scientific data and methods for risk assessment in Europe. The JRC has a long standing research programme in monitoring, modelling and assessing risk for various hazard types, including natural, human and combinations. While several Units are active in this area, it is not always an objective to create or collect data on hazards and risks in a pan-European database. More often, Units work on methodologies or underlying research. However, in the meeting it was

agreed to compile the available information from various Units into a technical report for ECHO.A.3, which will serve to have baseline data on risks in Europe. If relevant, this may also be the basis for defining specific projects with JRC to elaborate further on European wide risk assessments.

This technical report complements the information provided by Participating States by presenting information from existing JRC projects and databases covering the main natural hazards. This information includes projects, systems, methodologies and datasets collected through the Global Disaster Alert and Coordination System (GDACS) for earthquakes and tsunamis, European Flood Awareness System (EFAS) for floods, and European Forest Fire Information System (EFFIS) for forest fires, the European Drought Observatory (EDO) and work on industrial risk, natech risks and critical infrastructure.

The report is divided into chapters according to hazard type and/or cross-cutting theme. Various Units have contributed with data, statistics, maps, methodologies and/or analysis.

2 Methodology

Risk assessment is typically performed in different ways depending on the scientific and practitioner disciplines involved. In certain areas, science and policy is more advanced that in others. For the purpose of this report, authors were asked to structure their content in a harmonized way, as much as appropriate, and to follow the UNISDR definitions related to risk[1].

For this report, JRC did not perform extensive studies, analyses or data collection. Depending on the topic, the various authors provided a description of available data and/or expertise at JRC, current state of the field, a literature review and/or methodologies for future EU-wide assessments. Therefore, the report does not provide a comprehensive and multi-hazard risk assessment, but instead provides an overview of the state of the art in each theme.

Because of the summary nature of the report, it should be considered an internal Commission report, and not be distributed further without the author’s consent.

[1] http://www.unisdr.org/we/inform/terminology

3 Contents

4 Risk Assessment by Hazard Type

4.1 *Earthquakes*

4.1.1 Risk description

The earthquake hazard is relatively well known. The seismological community has created a harmonized product in 1999 under the Global Seismological Hazard Assessment Project (GSHAP)[2]. GSHAP maps typically show the maximum peak ground acceleration (pga) to be expected in a 50 year period. Ground acceleration is the effect of earthquakes that transfers destructive energy to buildings and infrastructure, causing damage and casualties. The maps are based on historical earthquake locations, frequency and magnitude, as well as known fault lines. The GSHAP maps are widely used in prevention for seismic zoning (dividing territory in risk zones according to the expected pga, and setting appropriate building codes), although it has known limitations[3]. Based on this data, the EPSON project has published hazard risk maps[4] in 2004, identifying the NUTS regions most at risk. More recently, the FP7 project SHARE[5] aims at improving the earthquake hazard maps taking into account the latest research and observations. In parallel, the Global Earthquake Model (GEM)[6] project started work on developing the scientific, software and training tools necessary for countries or regions to perform more detailed risk assessments.

While the seismic hazard is well known, the consequences are more difficult to assess in a top-down approach. Earthquakes can trigger secondary effects (like landslides, dam breaks, liquefaction) and local amplification (local soil conditions that amplify energy and cause more destruction), for which local knowledge is necessary. Furthermore, to assess the potential risk for infrastructure and population, local knowledge is required on vulnerabilities[7], including the location and structural engineering parameters of buildings, the applicable zoning and building codes, and the level of compliance with the codes. This data is generally not available at national or European level, obliging top-down risk assessments to make assumptions and therefore making them less precise. However, they are a useful tool to understand which regions are most at risk, and which need to be encouraged to make more detailed risk assessments.

4.1.2 Methodology for EU-wide risk assessment

The Joint Research Centre has been involved in earthquake risk science through various Units and actions, as well as through participation in FP7 projects[8] and other scientific projects

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[2] Giardini, D., 1999. The global seismic hazard assessment program (GSHAP), 1992/1999. Ann Geophys 42:957-974.

[3] Kossobokov, V., A. Nekrasova, 2011. Global seismic hazard assessment program (GSHAP) maps are misleading. Prob Eng Seismol 38(1):65-76.
Swafford, L., S. Stein, 2007. Limitations of the short earthquake record for seismicity and seismic hazard studies. In *Continental Intraplate Earthquakes: Science, Hazard and Policy Issues*, S. Stein and S. Mazzotti (Eds), The Geological Society of America.

[4] The European Spatial Planning Observation Network (EPSON) is set up to support policy development and to build a European scientific community in the field of territorial development. A comprehensive report (http://www.preventionweb.net/files/3621_Finalreport.pdf). The earthquake map is available at http://www.preventionweb.net/files/3825_earthquakehazardN3.jpg

[5] Seismic Hazard Assessment in Europe, CT-226967, http://www.share-eu.org.

[6] Global Earthquake Model. http://www.globalquakemodel.org

[7] Sarewitz, D., R. Pielke, M. Keykhah, 2003. Vulnerability and Risk: Some Thoughts from a Political and Policy Perspective, Risk Analysis, 23, 4, 805-810. doi:10.1111/1539-6924.00357t

[8] Syner-G – Systemic Seismic Vulnerability and Risk Analysis for buildings, lifeline networks and infrastructure's Safety Gain, CT-244061, http://www.syner-g.eu.

(including GEM). JRC is also running an operational earthquake impact assessment system in the framework of the Global Disaster Alert and Coordination System (GDACS). GDACS has collected earthquake data since 2003 in Europe and globally. However, JRC has not published a comprehensive risk assessment for Europe, mainly because of the limitations of a centralized top-down approach described above.

For this section, JRC used the GSHAP hazard data (mainly the peak ground acceleration at 50 year return period) and overlaid this with major cities (with population larger than 50000). Risk typically combines three elements, namely hazard, exposure and vulnerability (for the purposes of this report including resilience). Since there is no comprehensive data on vulnerability, it was not used for this report. To identify the risk level of European countries and cities, the risk was defined as the product of the percentile of the population exceeding 50000 people and the percentile of pga values for those cities:

$$risk = percentile\ (\ pop - 50000\ ) \times percentile\ (\ pga\ ).$$

4.1.3 Risk map of Europe

The methodology described above is applicable to all cities with population exceeding 50000. Given the distribution of the seismic hazard (Figure 1), the cities most at risk are located in zones where large earthquakes have been recorded by instruments or are known through historical records.

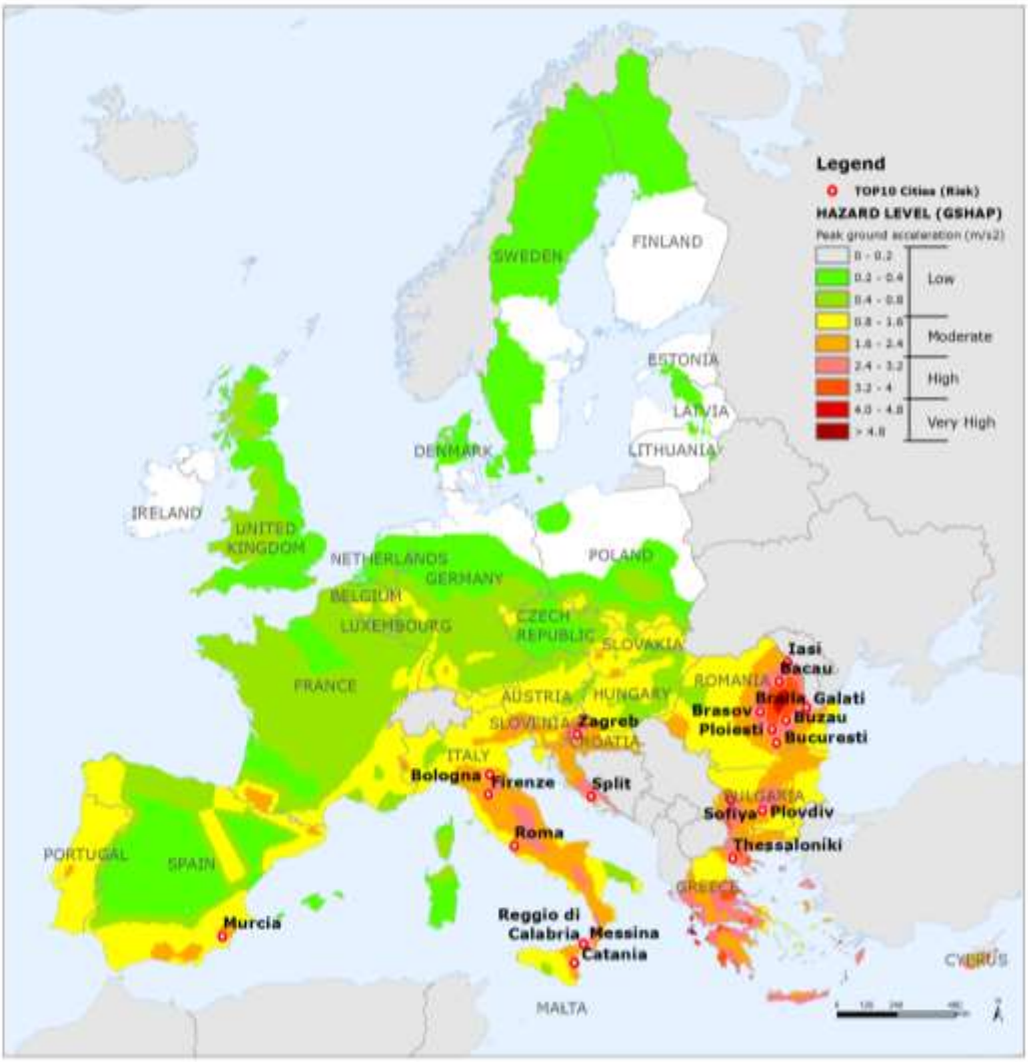

Figure 1. Earthquake hazard map, with top 20 cities at risk. Source: JRC. Data: GSHAP.

Table 1. Top 20 cities at risk for earthquakes.

City (population > 50000)	Country	Population	Peak Ground Acceleration (PGA) Source: GSHAP	Population Percentile	PGA Percentile	Risk Percentile
Zagreb	Croatia	686,771	2.9	0.992	0.992	0.985
Brasov	Romania	303,874	2.9	0.973	0.991	0.970
Thessaloniki	Greece	352,658	2.6	0.978	0.984	0.967
Galati	Romania	341,432	2.5	0.978	0.979	0.961
Sofiya	Bulgaria	1,091,857	2.2	0.996	0.958	0.954
Plovdiv	Bulgaria	336,317	2.4	0.978	0.975	0.957
Ploiesti	Romania	246,377	2.7	0.963	0.988	0.960
Iasi	Romania	351,965	2.4	0.978	0.972	0.955
Bacau	Romania	211,421	3.2	0.950	0.995	0.961
Messina	Italy	245,059	2.4	0.962	0.974	0.947
Bucuresti	Romania	1,840,470	2.0	0.998	0.937	0.935
Braila	Romania	229,791	2.4	0.956	0.966	0.937
Bologna	Italy	372,437	2.0	0.981	0.940	0.925
Firenze	Italy	367,988	2.0	0.981	0.929	0.914
Reggio di Calabria	Italy	181,374	2.4	0.936	0.973	0.931
Catania	Italy	300,140	2.0	0.973	0.935	0.914
Split	Croatia	174,550	2.4	0.931	0.972	0.928
Roma	Italy	2,540,654	1.8	0.999	0.903	0.902
Buzau	Romania	144,839	3.3	0.903	0.996	0.939
Murcia	Spain	404,453	1.8	0.983	0.908	0.894

4.1.4 Towards a comprehensive EU risk assessment

The key recommendations for more comprehensive and detailed risk assessments concern two aspects:

- **Improved hazard assessment**. The outcomes of on-going research projects will greatly improve the detail and accuracy of the seismic hazard. Future risk assessments must take this scientific data into account.

- **Vulnerability and resilience**. Risk assessments must take into account local knowledge on secondary risks (including landslides) as well as data on vulnerability (both physical vulnerability of buildings and infrastructure and social vulnerability of societies) and resilience (available coping mechanisms such as insurance coverage, effective response services and early warning systems).

4.2 Tsunamis

4.2.1 Risk description

Tsunamis are caused by earthquakes that occur under the sea, or large landslides (sometimes induced by collapsing volcano domes) that occur near the coast. Again, seismologists have produced quite precise hazard maps, both for tsunamogenic earthquake zones and for volcanic domes. More recently, advances in hydrodynamic modelling have produced databases of tsunami wave heights near the coast, based on tsunamogenic earthquake scenarios. This allows for precise modelling of the tsunami hazard along European coasts, including inundation and run-up estimates. An additional, but important aspect for the real hazard is the superposition of the tsunami wave with other phenomena, including tides and storm surges[9].

However, the associated risk is more difficult to assess. Like for earthquakes, local specificity can greatly increase of decrease the risk. The risk can be reduced by steep coastal geometry, coastal protective infrastructure or warning mechanisms. The risk may be increased by infrastructure at risk (e.g. nuclear plants), seasonal tourist activity (beaches), and local coastal amplification (typical in ports). This data is generally not available at national or European level, obliging top-down risk assessments to make assumptions and therefore making them less precise. However, they are a useful tool to understand which regions are most at risk, and which need to be encouraged to make more detailed risk assessments.

4.2.2 Methodology for EU wide risk assessment

For volcanic tsunamis, local risk assessments have been described in literature[10]. Seismic tsunami hazard risk is closely tied to seismic hazard risk (see section on Earthquakes). Using a large database of tsunami calculation scenarios (such as the one created by JRC[11]), it could be feasible to relate the probabilistic seismic hazard to coastal tsunami hazard. However, this analysis has not been done.

Regarding tsunami risk, several FP6 and FP7 research projects[12] considered specific scenarios (e.g. Messina (Italy), Fethiya, Istanbul (Turkey)) or aspects (improving modelling, data and measuring methods).

4.2.3 Risk map of Europe

In 2005, the EPSON project published[13] a risk assessment based on historical tsunami events and seismic hazard. The map classifies coastal areas in Europe according to the probability of a tsunami occurrence.

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[9] A.G Dawson, P Lockett, S Shi, 2004. Tsunami hazards in Europe, Environment International, 30, 4, 577-585, ISSN 0160-4120, 10.1016/j.envint.2003.10.005.

[10] For example Tinti S., E. Bortolucci, C. Romagnoli, 2000. Computer simulations of tsunamis due to sector collapse at Stromboli, Italy, Journal of Volcanology and Geothermal Research, 96, 1–2, 103-128, ISSN 0377-0273, 10.1016/S0377-0273(99)00138-9.

[11] Annunziato, A, 2007. The tsunami assessment modelling system by the Joint Research Centre. Science of Tsunami Hazards 26.2: 70-92.

[12] An overview is available at http://www.preventionweb.net/files/10785_TsunamiSTEFANOTINTIUNIVBOLOGNADAY1.pdf

[13] EPSON. http://www.preventionweb.net/files/3621_Finalreport.pdf

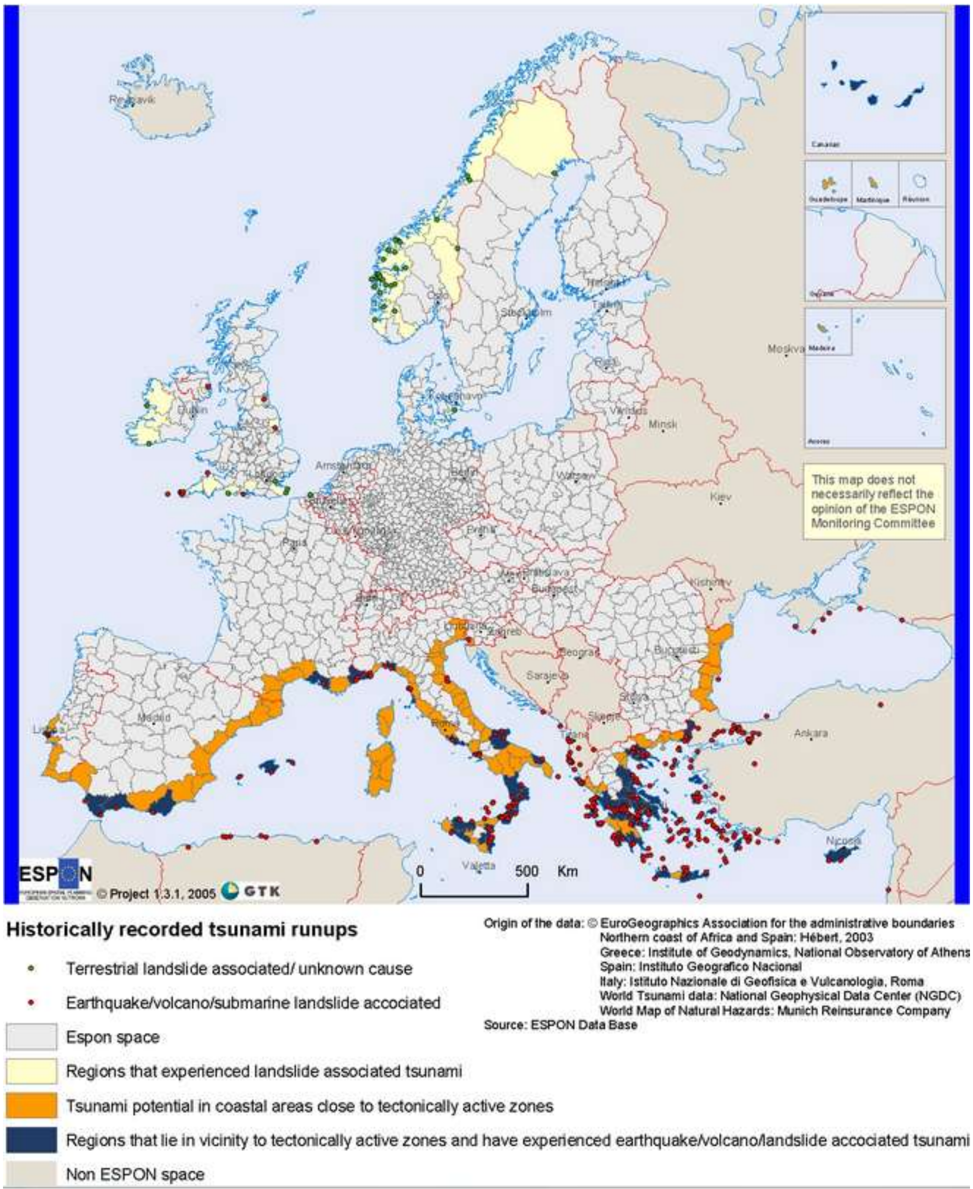

Figure 2. EU-wide tsunami risk. Source: EPSON. http://www.preventionweb.net/files/3831_TsunamihazardN3.jpg

4.2.4 Towards a comprehensive EU risk assessment

The key recommendations for more comprehensive and detailed risk assessments concern two aspects:

- **Improved hazard assessment**. New research is needed to calculate the probabilistic tsunami hazard associated with tsunamogenic earthquakes. This involves the inversion of existing tsunami scenario databases (e.g. the JRC tsunami database) and linking them with the probabilistic seismic hazard (from GSHAP or improved sources). If requested, the JRC can perform this assessment. Future risk assessments must take this scientific data into account.

- **Integrated coastal risk**. Coastal risk assessments must take into account all coastal phenomena and possible additive effects. In addition, local knowledge on coastal vulnerability and defences must be considered in risk assessments.

4.3 Floods

4.3.1 Flood Hazard and Risk – Introductory Remarks

Flood hazard and risk assessments will be part of the Flood Risk management plans under the Flood Risk Directive. The current timetable of implementation of the FRD foresees that flood hazard and risk maps should be submitted by the end of 2013. The final Flood Risk Management plans should be submitted by the end of 2015.

The JRC has been working on pan-European flood hazard and risk maps for various years. These maps are available at a spatial scale of 100m resolution and provide a harmonised, regional overview on flood hazard and risks across Europe. However, due to the spatial scale as well as to the incomplete or unavailable baseline data required to produce such maps, the pan-European maps cannot provide the same spatial detail and preciseness as the maps that will be (or have already been) produced by the Member States under the FRD. Hence, the pan-European flood hazard and risk maps should be considered as complementary to the actual more detailed national assessments. This should be clearly noted in order to avoid conflicts with Member State authorities.

Projections to 2020 could be extracted from the climate change scenarios that have been performed at the JRC.

4.3.2 Flood Hazard Map of Europe

JRC started working on approaches to generate a flood hazard map for Europe in 2007[14] and 2008[15]. In 2012, an updated flood hazard map was produced using a cascading models approach, which represents currently the latest, state-of-the-art approach to generate a high-resolution flood hazard map at large scales[16]. Comparisons with national flood hazard maps have illustrated a reasonable agreement between those datasets.

The pan European flood hazard map has a 100m x 100m pixel resolution and is available for return periods of 5, 20, 50, 100 and 200 years return period flood events. Figure 5 illustrates the European flood hazard for a 100-year return period event. For 2013, it is foreseen to apply this method also to various climate change scenarios.

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[14] Barredo, J.I., de Roo, A., Lavalle, C. (2007) Flood risk mapping at European scale. Water Science and Technology, Vol. 56, 4, 11-17.

[15] Barredo, J.I., Salamon, P, Feyen, L., Dankers R., Bodis, K., de Roo, A. (2008) Flood damage potential in Europe. Office for Official Publications of the European Communities, Luxembourg, Catalogue number LB-30-08-670-EN-C, ISBN 978-92-79-09769-0, DOI: 10.2788/95765.

[16] Alfieri, L., Salamon, P., Bianchi, A., Neal, J., Bates, P., Feyen, L. (2013) Mapping pan European flood hazard in Europe through two-dimensional hydraulic modeling. *To be submitted*.

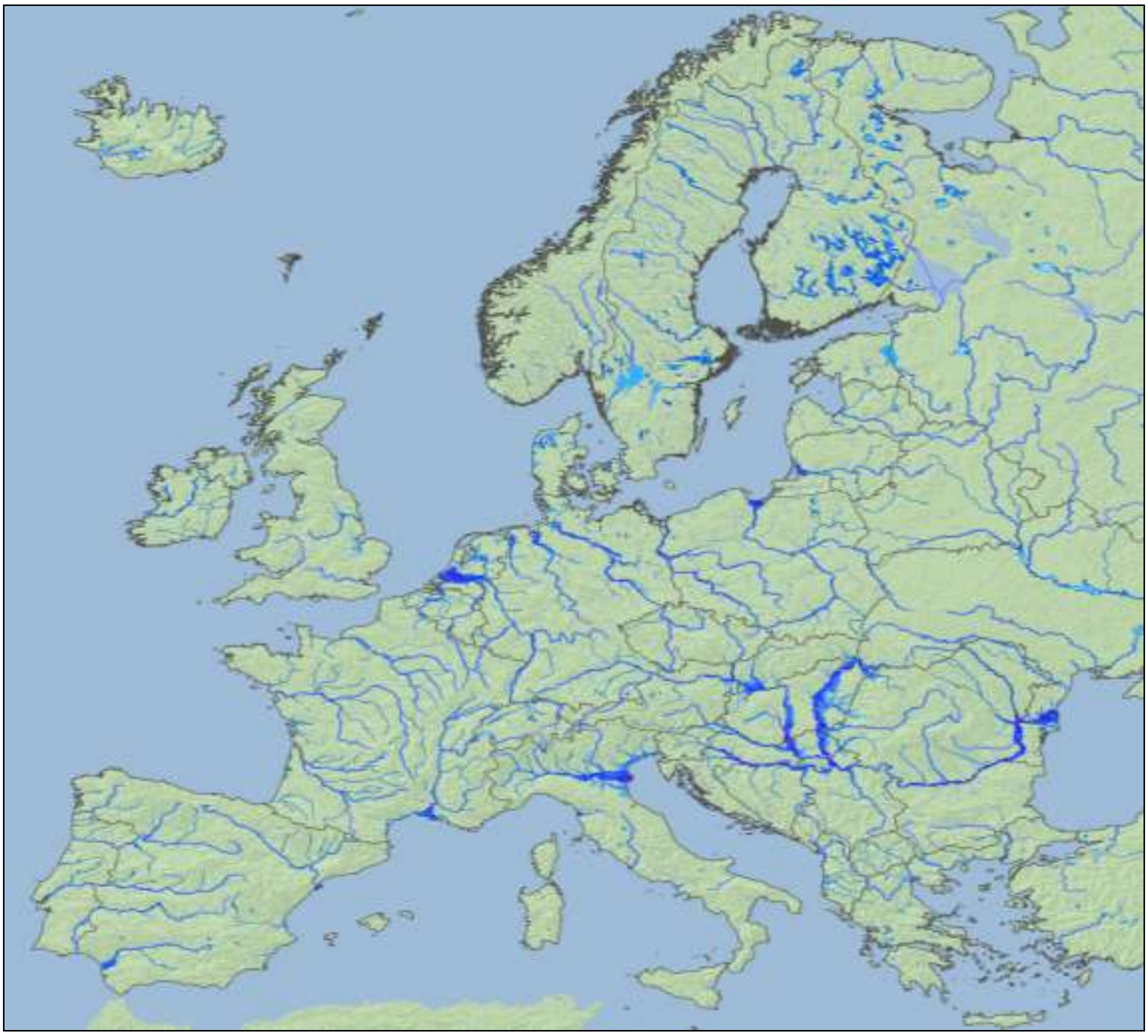

Figure 3: European flood hazard map for the 100-year return period.

4.3.3 Flood Risk map of Europe

Flood risk assessment requires the integration of the physical impact results (flood inundation extent and depth) with information on exposure and vulnerability or impact. For the damage assessment, exposure can be assessed based on the land use classification of CORINE Land Cover. Vulnerability, defined as the susceptibility of the exposed assets at contact with water, is appraised using country specific flood depth-damage functions[17]. The depth-damage functions represent, for each country and for each land use class (e.g., residential, industrial, etc.), the absolute amount of damage as a function of flood inundation depth. For different recurrence intervals, direct damage estimates can therefore be obtained by overlaying the flood water depth map with the land use map linked with the corresponding depth-damage functions. Figure 4 illustrates an example of continental scale flood damage potential for a 100-year flood represented at a 1 x 1 km grid and using purchasing power parities[18]. Note, that this assessment does not consider indirect or intangible costs in this approach.

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[17] Huizinga HJ (2007) Flood damage functions for EU member states. Technical report, HKV Consultants. Implemented in the framework of the contract # 382441-F1SC awarded by the European Commission-Joint Research Centre.

[18] Barredo, J.I., Salamon, P, Feyen, L., Dankers R., Bodis, K., de Roo, A. (2008) Flood damage potential in Europe. Office for Official Publications of the European Communities, Luxembourg, Catalogue number LB-30-08-670-EN-C, ISBN 978-92-79-09769-0, DOI: 10.2788/95765.

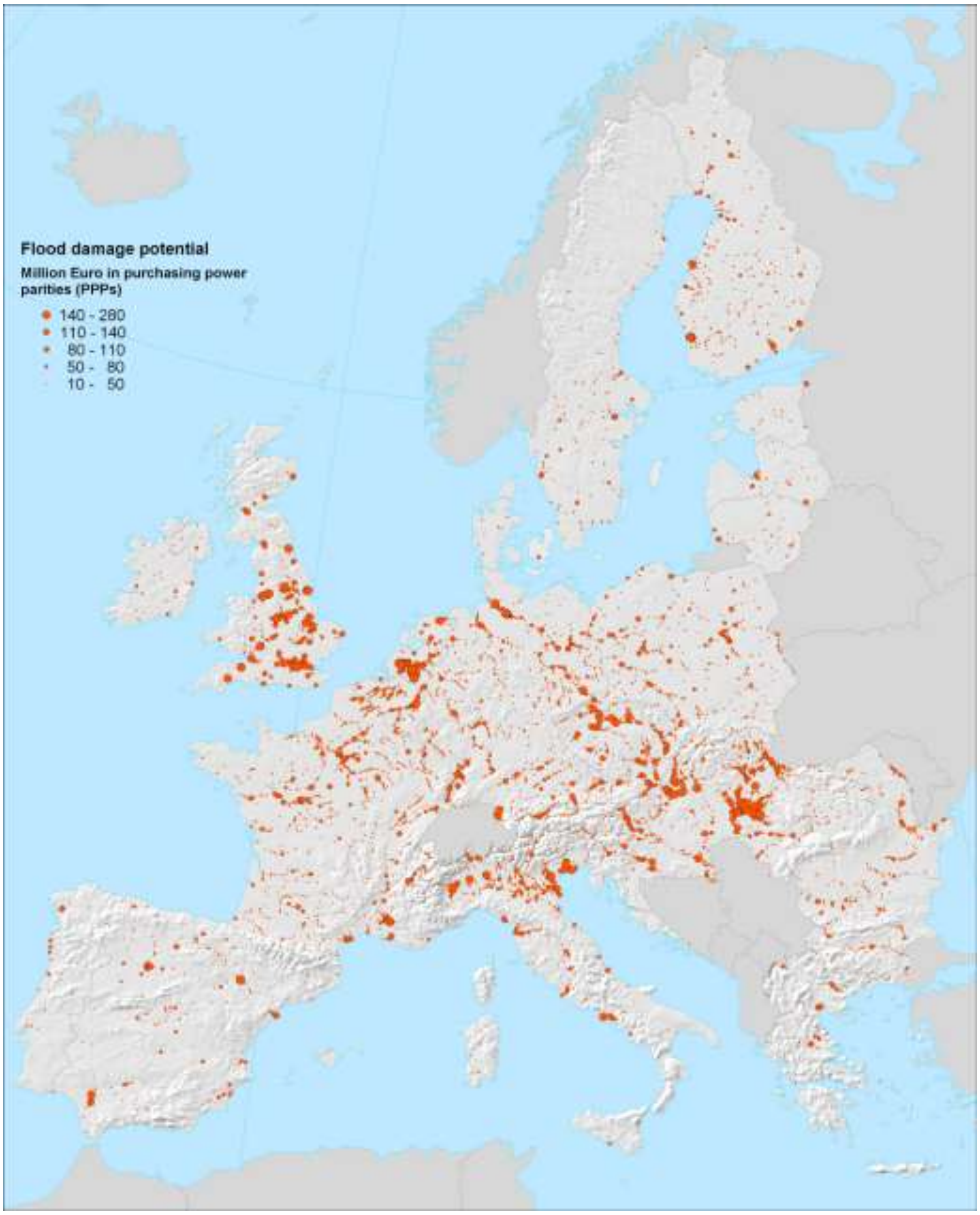


Figure 4. Map of damage potential of current 100-year flood

By linearly interpolating damages between different return periods, damage probability functions can be constructed for each grid cell. The integral of this function represents the expected annual damage (EAD) at the particular location due to flooding. In reality, most countries have flood defence measures up to a certain design flood to prevent areas from flooding. However, data about flood protection levels, including their probability of failure, are hardly available at the national or European level. To account for flood protection the damage-probability functions need therefore to be truncated at the corresponding design return period. In this way, damages from floods with lower return periods are discarded. The integral of the remaining part of the function corresponds to the expected yearly loss due to flooding taking into account flood protection measures. This approach has been followed to assess changes in flood damage in view of climate change[19]. An example for such an assessment of the expected annual damage of flooding is illustrated in Figure 5.

[19] Feyen, L., Dankers, R., Bódis, K., Salamon, P., Barredo, J.I. (2012) Fluvial flood risk in Europe in present and future

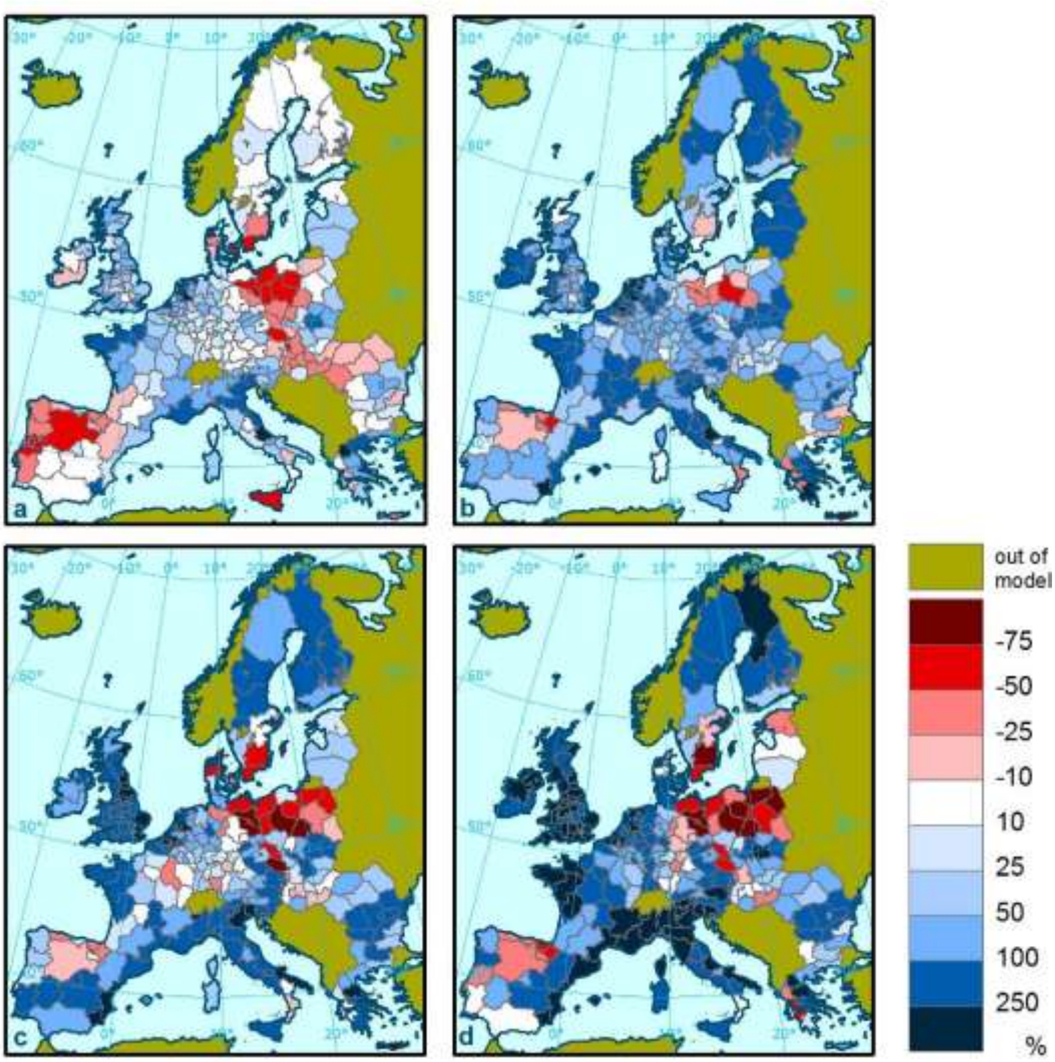


Figure 5: Change in Expected Annual Damages (averaged over administrative level NUTS2) from floods compared to the baseline period (1961-1990) for the 2000s (a), 2020s (b), 2050s (c) and 2080s (d), all for the A1B scenario. Ensemble average results based on LISFLOOD simulations driven by 12 regional climate models for the IPCC SRES A1B scenario (Rojas et al., 2013).

Similar approaches can be applied to derive the population exposed to floods. It is currently planned that in 2013 an updated map of the economic damages of flooding based on the latest flood hazard map as outlined above is generated. Furthermore, similar assessments are foreseen for various climate change ensemble runs.

climates. Climatic Change, Vol. 112, 1, 47-62.

Rojas, R., Feyen, L., Watkiss, P. (2013) The Impacts and economic costs of river floods in the European Union and the costs and benefits of adaptation. To be submitted.

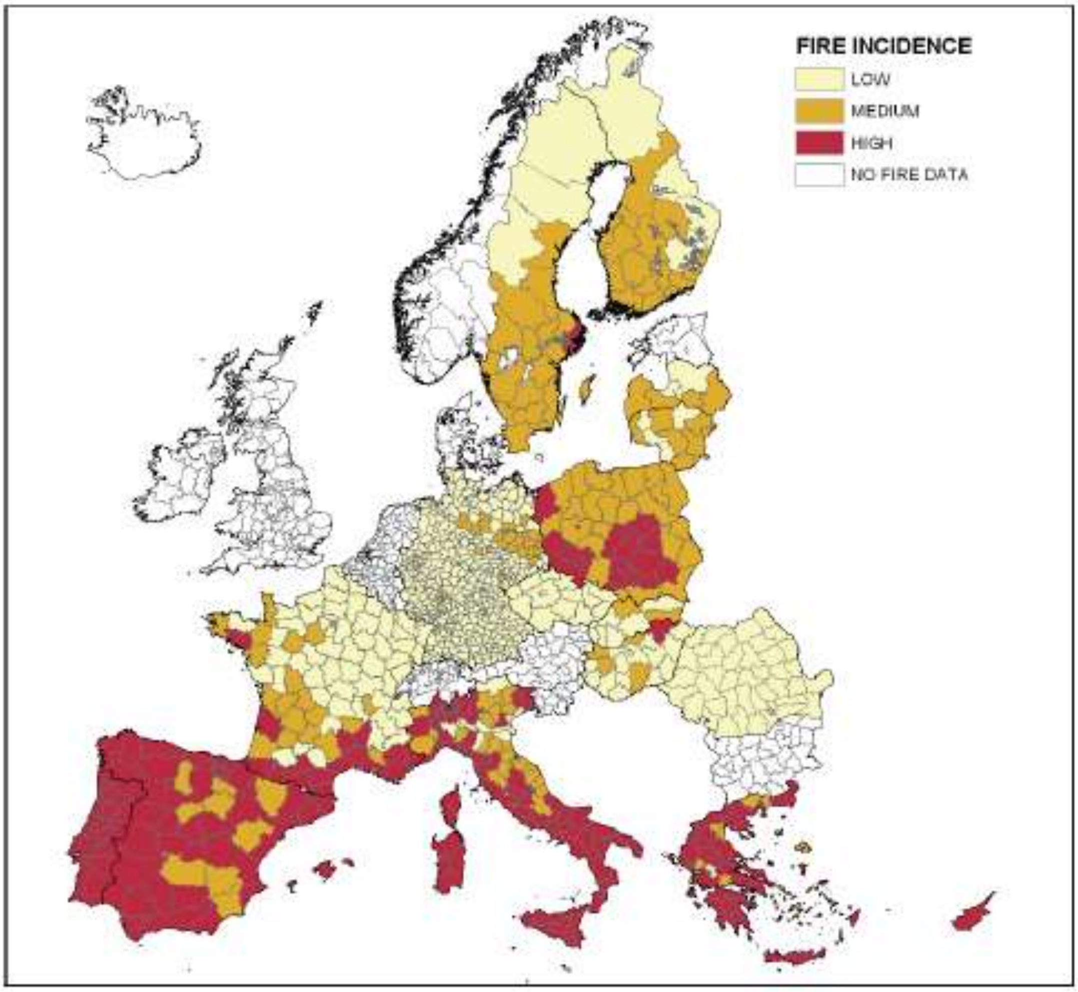
4.4 Forest fires

4.4.1 Risk description

Forest fires are a recurrent phenomenon in the European territory. Approximately 65000 forest fires take place every year in the European Union burning, on average, half a million hectares of forest and natural lands. The main direct effect of forest fires is the destruction of the natural landscape and the consequent loss of ecosystem services that have drastic economic impact. Yearly economic losses due to forest fires are estimated in about €2 billion. Forest fires are not evenly distributed in Europe; fire impact is highly dependent on the meteorological conditions under which the fires take places. Drought, high temperatures and fast winds facilitate fire ignition and spread. Since these conditions are often found more frequently in southern EU countries, these are the ones suffering most of the damages caused by fires. Approximately 85% of the total burnt area in Europe occurs in the EU Mediterranean region. In addition to ecological and economic losses, fires result in the loss of human lives every year. The most critical episode in the recent years was the fires in Greece, which lead to the dead of 80 people among civilians, and fire fighters in 2007.

4.4.2 Risk map of Europe

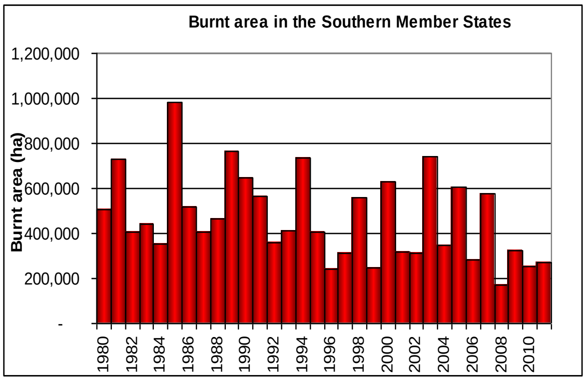
Fire risk is often computed as the combination of fire danger and fire vulnerability; it includes parameters related to fire ignition and propagation, as well as those related to the potential impact of the fires. In a simple approach, it is possible to assess the incidence of forest fires on the basis of fire statistics from past years; this approach was used to derive the map presented in the figure below.

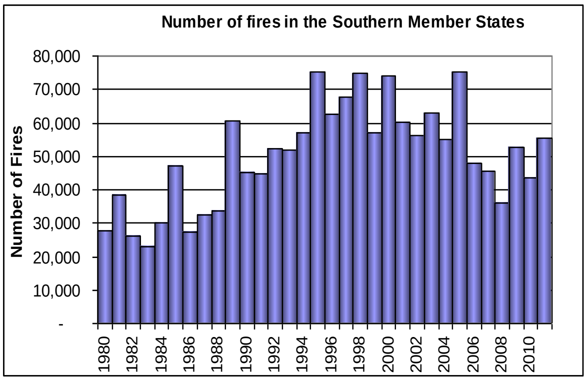


In this figure, areas with high fire incidence are those in which the either the number of fires or the burnt area statistics in the past years were considered high or very high. A more complex methodology taking into account other fire related variables such as fuels, topography, etc. will lead to a comprehensive fire risk map at the European level.

4.4.3 Specific risk assessments

Most of the damages caused by forest fires are concentrated in just 5 EU Mediterranean countries: Portugal, Spain, France, Italy and Greece. The figures below show the trends in the number of fires and the burnt areas in these countries during the last decades. These trends show a high variability from year to year. The statistical variability goes next to a spatial variability in the location and effect of forest fires. Critical fire damages during the last decade occurred in Portugal in 2003 and 2005, in Spain in 2005, 2006 and 2012, France 2003, and in Italy and Greece in 2007.





The table below shows the number of fires and the total burnt area in the EU Mediterranean countries in the last decades.

Number of fires	PORTUGAL	SPAIN	FRANCE	ITALY	GREECE(*)	TOTAL
2011	25 221	16 028	4 500	8 181	1 613	55 543
% of total in 2011	45%	29%	8%	15%	3%	100%
Average 1980-1989	7 381	9 515	4 910	11 575	1 264	34 645
Average 1990-1999	22 250	18 152	5 538	11 164	1 748	58 851
Average 2000-2009	24 949	18 337	4 406	7 259	1 695	56 645
Average 2010-2011	23 624	13 875	4 200	6 533	1 333	49 564
Average 1980-2011	18 533	15 243	4 904	9 783	1 554	50 017
TOTAL (1980-2011)	593 052	487 788	156 931	313 042	49 723	1 600 536

Burnt areas (ha)	PORTUGAL	SPAIN	FRANCE	ITALY	GREECE	TOTAL
2011	73 813	84 490	9 630	72 004	29 144	269 081
% of total in 2011	27%	31%	4%	27%	11%	100%
Average 1980-1989	73 484	244 788	39 157	147 150	52 417	556 995
Average 1990-1999	102 203	161 319	22 735	118 573	44 108	448 938
Average 2000-2009	150 101	125 239	22 342	83 878	49 238	430 798
Average 2010-2011	103 452	69 630	9 965	59 271	19 056	261 373
Average 1980-2011	108 275	170 397	26 946	112 955	46 742	465 314
TOTAL (1980-2011)	3 464 789	5 452 717	862 262	3 614 546	1 495 735	14 890 049

4.4.4 Methodological notes

Forest fire data are provided by the EFFIS network countries on an annual basis; these data are used to derive European statistics and to calibrate and validate additional data produced by the JRC at the European scale. Fire risk of often estimated as a combination of fire vulnerability and fire danger, including this latter term the fire intensity and destructive capacity.

4.4.5 Towards a comprehensive EU risk assessment

A EU forest fire risk assessment should build on the work and collaboration already established between the Member States and the EC in the context of the European Forest Fires Information System (EFFIS). This follows the agreements already existing in the area of forest fires for the further development of EFFIS and the Council Conclusions of 2010 on forest fire prevention in the EU.

4.5 Droughts

4.5.1 Drought Hazard and Risk – Introductory Remarks

Drought risk is a combination of the natural drought hazard and societal vulnerability. Currently no drought risk assessment as such exists for Europe. The topic and potential methodologies (including the issue of adequate data) is currently under discussion in the Water Scarcity and Drought Expert Group (WS&D EG) under the Common Implementation Strategy for the Water Framework Directive (WFD-CIS). JRC is a member of this expert group. While 2011 and 2012 led to the adoption of a suite of drought indicators for monitoring and assessing drought events, the drought hazard and risk assessment will be in the focus in 2013.

Drought hazard and risk assessments will be part of the River Basin Management Plans under the WFD. However, they may be available only for river basins in drought prone areas.

In the meantime, JRC has implemented some first attempts to estimate drought hazard across Europe based on data available through the European Drought Observatory (EDO), developed and maintained at JRC. These hazard maps are preliminary and as such need further elaboration and validation. This should be clearly noted in order to avoid conflicts with Member State authorities.

Projections to 2020 will only be possible, once the methodologies for both hazard and risk assessment have been consolidated and accepted.

The following sections provide the results of these first attempts to assess drought hazard across Europe. The maps are confined to the ESPON area, for which they have been prepared. They can be completed for the entire European continent, if needed. This map will be published in an ESPON Report shortly.

4.5.2 Drought Hazard Map of Europe

Drought refers to a temporal, albeit prolonged shortfall in precipitation as compared to the climatological normal for a defined period of time. It occurs in all climates and as such it is to be distinguished from aridity. Different to other natural hazards, drought is a slowly developing phenomenon with widespread impacts over extended regions. Due to its complexity, no universal definition of a drought exists. However, depending on the impact, we usually distinguish between meteorological, agricultural, hydrological and socio-economic drought. Due to this complexity, many indicators have been proposed to evaluate the occurrence, duration, and intensity of a drought. A meteorological indicator has been used to estimate drought hazard in this case.

Over the last 15-20 years the number of drought events in Europe has increased compared to the 1951-1990 period. This increase might in part be due to the effects of climate change, leading to rising air temperatures and an increasing number of summer heat waves or extremely dry winters.

On a European basis, the mean value of the drought frequency during 1991-2010 is 14.0% with a standard deviation of 2.5%. The drought hazard has, therefore, been classified as shown in Table 2.

A hazard is related to exceptional conditions. We, therefore, classify normal conditions as low drought hazard. Note that a low value does not imply that there will be no drought events. It is expected that in the next 20 years the green regions will experience a relatively low frequency

of drought events, while the yellow, orange, and red regions have a higher probability of drought occurrence.

Table 2. Classes of Drought Hazard

Drought Hazard	Drought Frequency
Very Low	< 10%
	10% - 12%
	12% - 14%
	14% - 16%
	16% - 18%
	18% - 20%
Very High	> 20%

Each NUTS unit has been assigned the average value of drought frequency of the grid points falling into the NUTS unit.

The resulting map demonstrates that regions with a moderate or high drought hazard are predominantly located in the Mediterranean region, especially the Iberian Peninsula, southern France, parts of Italy and Greece, and Cyprus. Central Europe, UK and Scandinavia are characterized by a low or very low hazard. Parts of the Baltic States, due to the heavy drought of 2005 and 2006, show a drought frequency just above the normal value. Ireland and the Carpathian Region show a high drought frequency. Ireland has high rainfall regimes, but in 2003, 2004, and 2005 the annual amount of precipitation has been significantly lower than the long-term mean. Therefore, some Irish regions result to be in high drought hazard. We recommend handling the result of North-Eastern Ireland with care. The Carpathian Region, including large parts of Hungary and Romania, are among the regions at highest drought hazard over the last 20 years.

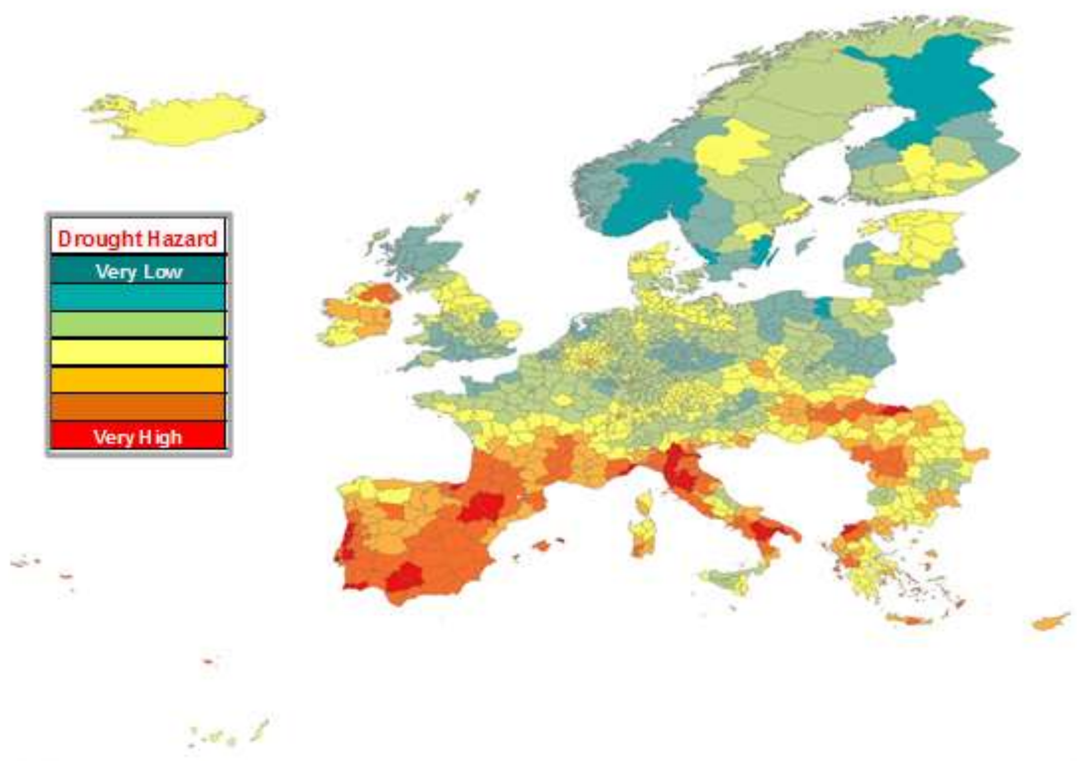


Figure 6. Drought Hazard (based on drought occurrence during 1991 to 2010) © JRC – 2012.

4.5.3 Risk assessment

Drought risk has not been assessed yet. The necessary data on societal vulnerability need to be collected and analysed.

4.5.4 Methodological notes

4.5.4.1 Data

Drought hazard has been derived from temperature and precipitation as input variables. Calculations are based on quality-checked and homogenized monthly mean temperature and precipitation data for the period 1951-2010 (60 years). In the area of interest (see Figure 1), approximately 2,050 meteorological stations were used. The dataset was formed by merging three datasets: JRC-MARS (Joint Research Centre - Monitoring Agricultural Resources Meteorological Database), KNMI-ECA&D (Koninklijk Nederlands Meteorologisch Institute, European Climate Assessment and Dataset), and NCDC-GSOD (U.S. National Climatic Data Center, Global Summary of the Day). E-OBS gridded products (version 7.0, by KNMI-ECA&D) have been used to complete missing months.

Please note that the Icelandic stations are located on the coast only and winter precipitation in Iceland may be significantly biased by snow. Even though the Icelandic stations passed the homogeneity tests, the precipitation records should be handled with great care.

4.5.4.2 Drought Indicator

The drought indicator chosen for the calculation of drought hazard is the 3-month Standardized Precipitation-Evapotranspiration Index (SPEI-3)[20]. It is a statistical indicator based on a 3-month accumulation of the climatic water balance, which is the difference between the precipitation and the potential evapotranspiration (PET). Here, PET was calculated using mean temperature and the Thornthwaite's model. SPEI is preferred to pure precipitation indicators as it includes also temperature, which is important in a climate change environment. For every station, SPEI-3 has been calculated for a moving 3-month window over the entire 1951-2010 record. A spatial interpolation based on radial distance, elevation difference, and distance from the coast has been performed for every month in order to project SPEI-3 monthly values onto a 0.25°x0.25° European regular grid.

SPEI is a standardized value, derived by approximation of the empirical distribution of the accumulated climatic water balance by a shifted Gamma distribution. Following the commonly adopted scale, we identify a drought when SPEI-3 is lower than -1 (corresponding to the coloured classes in Table 1).

Table 3. SPEI Classes

SPEI < -2.0	Extremely Dry
-2.0 < SPEI < -1.5	Severely Dry
-1.5 < SPEI < -1.0	Dry
-1.0 < SPEI < 1.0	Normal Conditions
1.0 < SPEI < 1.5	Wet
1.5 < SPEI < 2.0	Severely Wet
SPEI > 2.0	Extremely Wet

[20] Vicente-Serrano S.M., S. Beguería, J.I. López-Moreno (2010): A Multi-scalar drought index sensitive to global warming: The Standardized Precipitation Evapotranspiration Index - SPEI. Journal of Climate, vol. 23, 1696-1718. DOI: 10.1175/2009JCLI2909.1

4.5.4.3 Drought Hazard Assessment

Drought hazard is best estimated by the probability of occurrence of a certain drought event. Statistically, such probability can be estimated from the frequency of occurrence of past events. Assuming that the recent past is the best predictor for the next future, we based our map on the percentage of months under drought condition (i.e. SPEI-3 < -1) during the period 1991-2010 (240 months) as compared to the statistical distribution over the period 1951-2010 (720 months).

If a grid point experienced 12 months with SPEI-3 < -1 during 1991-2010, for example, its drought frequency over the last 20 years is 5%. It is fundamental to keep in mind that such a percentage does make sense only when it is calculated on a time period shorter than the time period used to calculate the underlying statistical distribution. If the percentage was calculated over the entire 60 years, it would result in fixed values given by the probability density function of the Gamma distribution.

4.5.5 Towards a comprehensive EU risk assessment

In order to provide a comprehensive drought risk assessment across the EU, first the drought hazard needs to be assessed in a comprehensive manner. That means probably considering different drought indicators to analyse the various aspects and impacts of drought.

Second, the societal vulnerability needs analysis and mapping. This will include aspects such as population distribution, water needs for different sectors (e.g., agriculture, households, and energy production), potential impacts of water shortages on different economic sectors as well as the environment, and other aspects.

Third, once these data and the methodology are established a comprehensive risk assessment can be done. Considerable progress on this matter is expected during 2013.

4.6 Natech disasters

4.6.1 Risk description

Given the increasing importance of risks due to the interaction of natural and man-made hazards (Natech risk) information on the dynamics of Natech accidents and the development of methodologies and tools for Natech risk assessment is required. In this regard, data from the JRC's eNatech database, as well as JRC Natech risk assessment methodologies and tools could be useful for the prevention and mitigation of future Natech accidents.

4.6.2 Risk map of Europe

Recent surveys performed by the JRC have shown that hardly any Natech risk maps are available within the EU MS. Where existing, Natech risk maps simply overlay natural and technological hazards without considering site-specific features or the interaction of hazards. The need for a systematic Natech risk-mapping methodology is therefore evident. Consequently, the JRC has developed the web-based Natech risk analysis and mapping tool RAPID-N which supports the decision-making process by identifying Natech -prone areas and by analysing and visualising Natech risk. Figure 7 shows an example Natech risk map for a hypothetical earthquake impact on a refinery in a EU MS using the RAPID-N tool.

The JRC performed a questionnaire survey to assess the status of Natech risk management in the EU. Data from 14 EU MS were obtained. This survey collected data on Natech risk assessment and management practices, identified Natech accident case histories and lessons learned, and highlighted needs and/or limitations in implementing Natech risk reduction strategies in the EU[21]. In almost 55% of the responding countries Natech accidents occurred, with the most frequent accident trigger being lightning, river floods and low temperatures. In almost half of the responding countries Natech risk seems not to be adequately taken into account in the industrial risk assessment process.

The JRC also maintains an accident database that was designed to capture the specific characteristics of Natech accidents. The database can be accessed at: http://enatech.jrc.ec.europa.eu. Its main purpose is to serve the lessons-learning process and consequently the preparation of recommendations for industry and authorities for reducing Natech risk[22].

4.6.3 Specific risk assessments

The JRC tool RAPID-N, which has currently been implemented for earthquakes, can be used for land-use- and emergency-planning purposes but also for preliminary damage assessment immediately after an earthquake. With this tool, the Natech risk can be analysed and mapped either locally for individual hazardous installations in natural-hazard prone areas, or simultaneously for all hazardous facilities that lie inside a user-defined area in the natural-hazard's impact zone. The results are shown as risk maps and risk summary reports. An example output is provided in Figure 7. The JRC has started using RAPID-N for assessing the Natech risk at the local and regional level.

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[21] E. Krausmann, *Analysis of Natech risk reduction in EU Member States using a questionnaire survey*, EUR Report 24661 EN, European Union, 2010.

[22] E. Krausmann, E. Renni, V. Cozzani, M. Campedel, *Major industrial accidents triggered by earthquakes, floods and lightning: Results of a database analysis*, Nat. Haz. 59/1 (2011) 285-300.

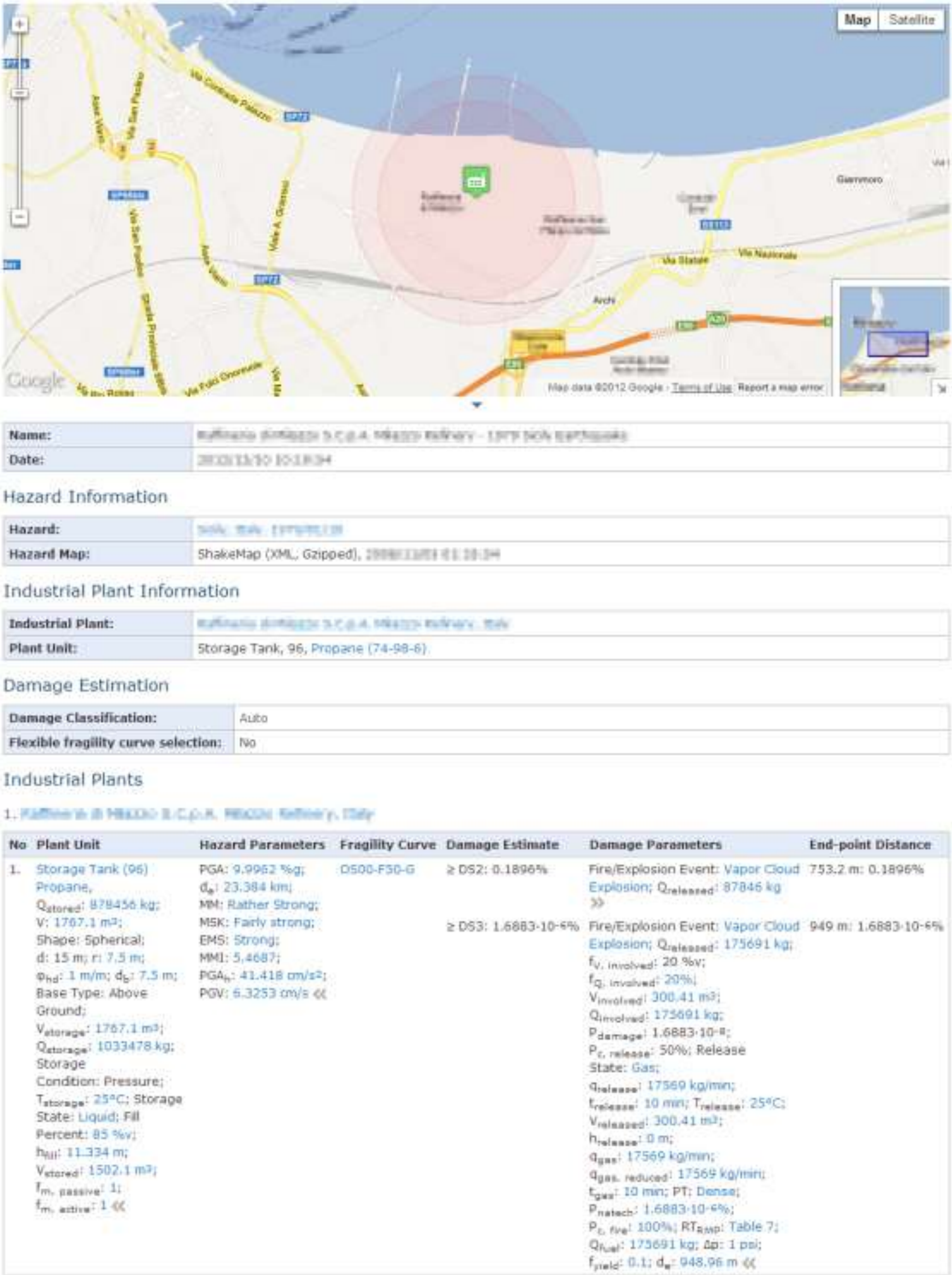

Figure 7. Example risk map and table for a hypothetical earthquake impact scenario on a refinery.

RAPID-N offers data on earthquakes (it follows the USGS and EMSC earthquake catalogue and contains all USGS Shakemaps), as well as on fragility data for specific types of equipment. Information on industrial facilities and equipment, as well as the Natech risk assessment made for these sensitive facilities is restricted. Provided data availability, RAPID-N can quickly give an estimation of the Natech risk.

4.6.4 Methodological notes

The RAPID-N tool integrates a unified, probabilistic methodology for Natech risk assessment and mapping. In order to facilitate usage of the tool, RAPID-N contains a powerful property

estimation framework which allows the user to perform Natech risk assessment with a minimum of data input.

It should be pointed out that all risk assessment methodologies and tools have inherent uncertainties that need to be considered in the decision-making process. Care must be exercised when trying to compare risk figures for different types of risks but also when extrapolating results for a single risk beyond the original assumptions on which the risk assessment was based.

4.6.5 Towards a comprehensive EU risk assessment

A number of research and policy challenges and gaps exists that can prevent effective Natech risk reduction. This includes a lack of data on equipment vulnerability against natural hazards and thus a lack of a consolidated methodology for Natech risk assessment. Further research is required to address these gaps.

Industrial risk assessment methodologies vary across the Member States, ranging from fully probabilistic to deterministic approaches and from fully quantitative to only qualitative. Prescription and harmonisation of risk assessment methodologies has never been achieved because of differences in safety cultures. Therefore, EU level tools and approaches for risk assessment are needed to ensuring a minimum comparability of results. These tools and approaches for instance should focus on standardising a number of necessary components, such as input and output formats, scenarios and data sources. The JRC has already produced significant contributions in this regard, but considerable work still needs to be done, building on the existing JRC collaboration with government, industry and academia in support of Natech and industrial risk reduction in general.

4.7 Industrial risk mapping and assessment

Contributors: Maureen Wood and Enrico Guagnini (EC-JRC-Major Accident Hazards Bureau (MAHB))

4.7.1 Risk description

Hazardous installations represent a major source of risk for the human population and the environment. Hazardous installations are generally considered those that have on site a significant[23] quantity of one or more substances with properties hazardous to human health or the environment. Processes associated with such installations often involve chemical products and process conditions with hazardous properties such as toxicity, flammability or high temperatures and pressures. It is therefore of great importance to understand the potential hazards involved in such activities, and to keep information and maps that illustrate the possible consequences of any accident that could happen at an industrial installation. Typical activities covered in this category include the processing or storage of petroleum, petroleum products and other minerals; processing or storage of chemicals used in bulk to manufacture a wide variety of chemical-based products; manufacturing of the products themselves, e.g., cleaning agents, pharmaceuticals, cosmetics, textiles, paint and inks, plastics and resins, etc.; as well as energy production, and the manufacture and storage of food and beverages.[24]

Single chemical accident releases involving dangerous substances in chemical installations petrochemical and oil refineries continue to happen frequently enough in Europe and demonstrate the need for better and more efficient control of major industrial hazards. Industrial accident prevention and preparedness in Europe is aimed not only at preventing major catastrophes, such as the fire in the petroleum storage depot at Buncefield (United Kingdom, 2005) or the ammonium nitrate explosion in Toulouse (France, 2001), but also at the small catastrophes that violate the right to a safe community, a safe workplace and a clean environment. Figure 1 below shows the number of major accidents in the eMARS chemical accident database in EU, EEA and EFTA countries from 2001 – 2010 [25].

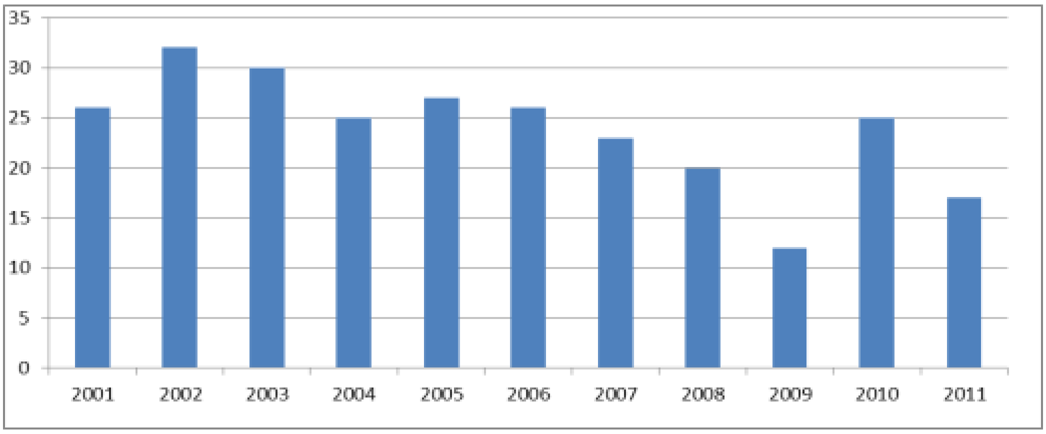

Figure 8. Number of Major Accidents in the eMARS database from 2001 – 2011 (European Commission Joint Research Centre, 2012)

[23] The quantity that is significant varies from substance to substance and depends on the potency and type of hazardous property.

[24] Salas J, M Wood and R Jelinek. 2007 Risk Mapping of Industrial Hazards in New Member States. Major Accident Hazards Bureau (MAHB), Joint Research Centre, European Commission, EUR 18124 EN.

[25] In accordance with the Seveso II Directive (96/82/EC) for the control of major hazards involving dangerous substances Member States must report all major chemical accidents occurring in Seveso establishments to the European Commission. These accident reports are available to the public online at https://emars.jrc.ec.europa.eu.

Notably, since 2010, major industrial accidents in Europe have been responsible for approximately 20 deaths, 70 injuries, evacuation or shelter-in-place of several thousand citizens, not mentioning damage to property and the environment, which account for millions of Euros, the extent of which cannot be fully calculated. A major accident is defined by criteria listed in Annex VI of the Seveso Directive. Figure 2 shows that the injury or death caused by the accident was the most prevalent criterion for reporting the accident database. It should be noted that many of the accidents involving injuries and fatalities also may have had minor or major property and environmental damage in addition.

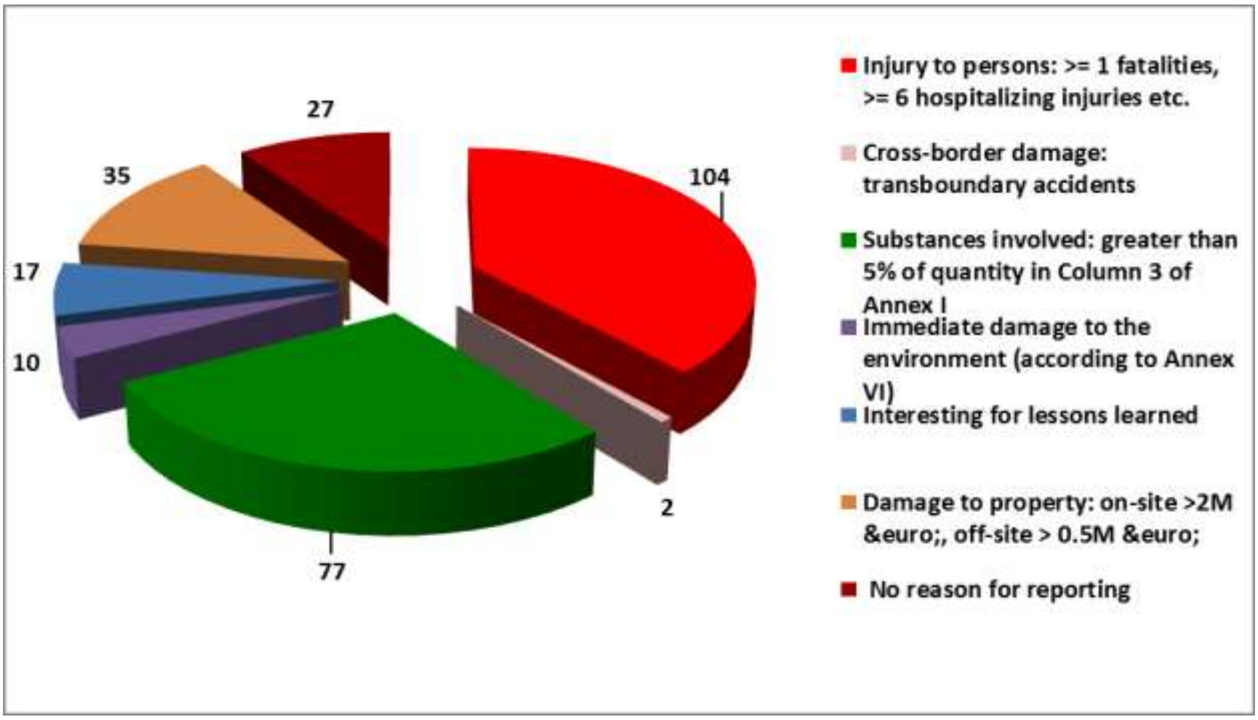

Figure 9. Accidents in eMARS as classified by the Seveso Annex VI Criteria (Source: EC-JRC-MAHB 2012)

4.7.2 Major hazard establishments in EU and EEA countries[26]

The number of Seveso establishments per country is illustrated in Figures 3 and 4. At the end of 2012, there were 9778 Seveso establishments according to data submitted to the European Commission's SPIRS database. The Seveso Directive divides establishments into two tiers according to the quantity of toxic, flammable, explosive or other dangerous substances. Establishments meeting the higher and lower quantity thresholds are considered upper and lower tier sites, respectively. Of the total EU/EEA establishments indicates that approximately 47% were upper tier status and 53 % were lower tier status in 2012. Typically, the most industrialised countries have the most establishments. Germany, France, Italy and the United Kingdom account for more than half (55%) of total establishments in Europe.

[26] Excerpt from Salas J, M Wood and R Jelinek. 2007 Risk Mapping of Industrial Hazards in New Member States. European Commission. Joint Research Centre (Ispra, Italy). EUR 18124 EN, pp. 9-10.

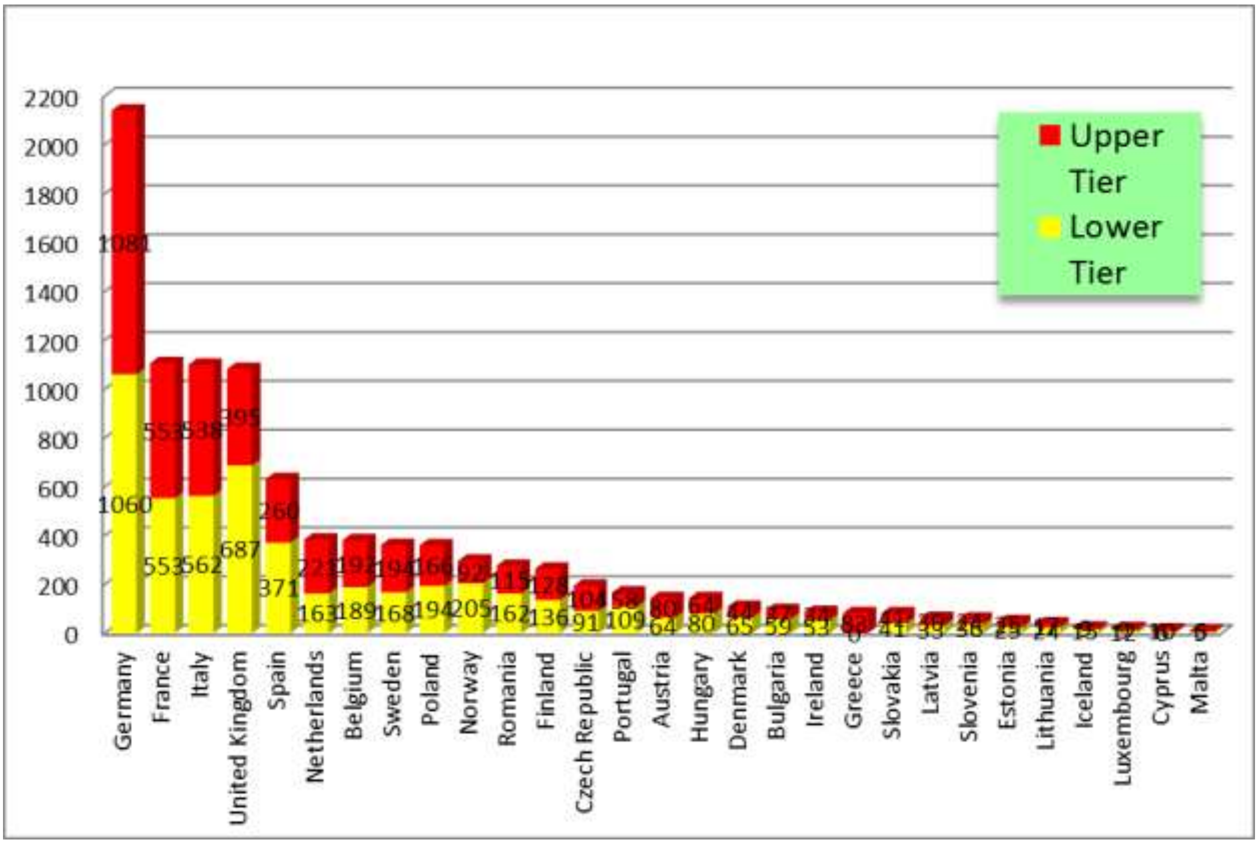

Figure 3. Upper tier and lower tier establishments per country in ranked order (Source: EC-JRC-MAHB 2012)

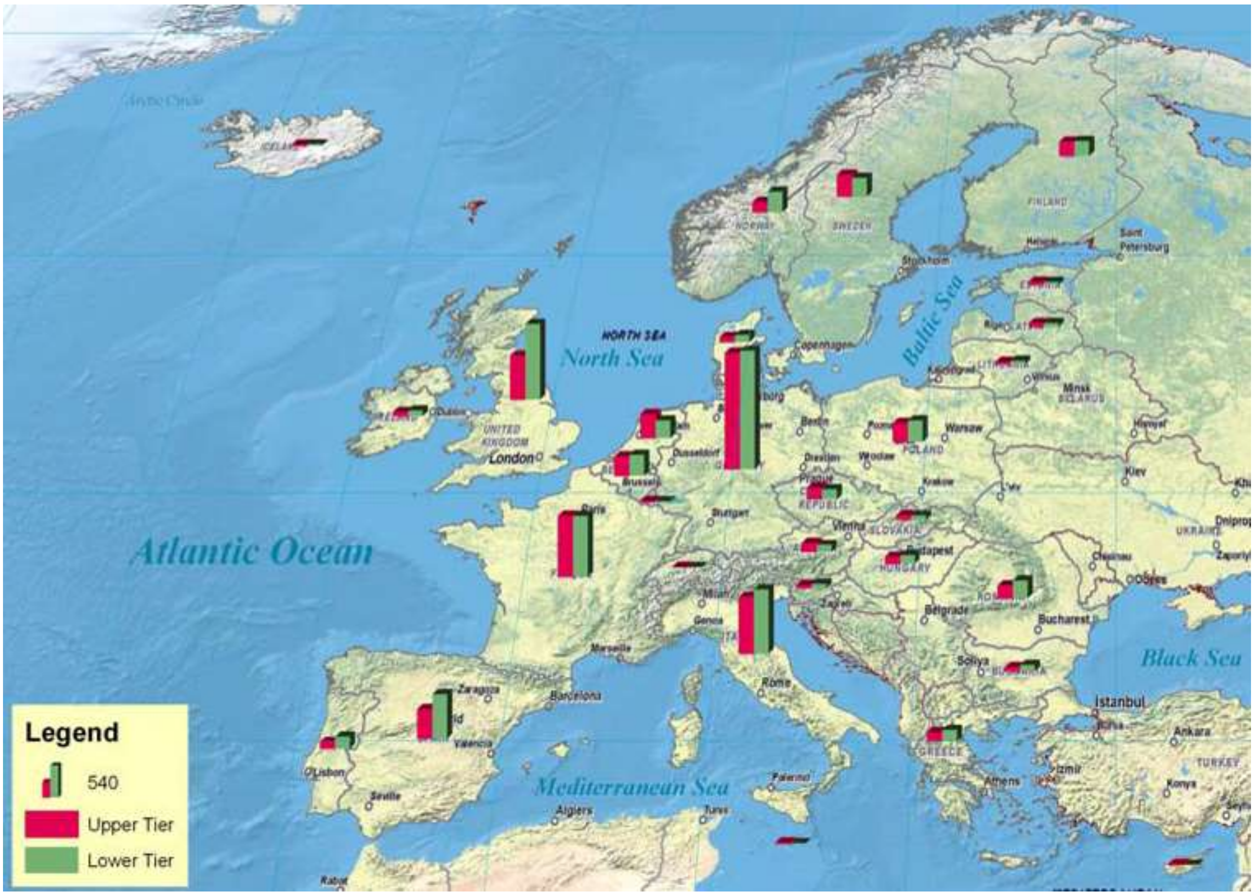

Figure 4: Mapped illustration of upper and lower tier Seveso establishments per country (EU and EEA) order (Source: EC-JRC-MAHB, 2012)

4.7.3 Approaches to mapping industrial risks[27]

Mapping of industrial hazards and accident risks may be fairly simple, consisting of points on a map identifying the location of particular hazardous installations and the type and quantity of dangerous substances they use. The mapping of potential accident scenarios is a more sophisticated mapping technique for industrial hazards. These types of maps will indicate the extent and intensity of the physicochemical effects (toxic release, fire or explosion) predicted for a potential accident scenario. For example, such a map may show the concentration level of a toxic cloud at a predefined distance, the thermal radiation of a fire or the overpressure generated by an explosion. Moreover, this type of mapping requires very specific local data. In addition, it may require specific expertise and resources, such as modelling software, that increase the expense and effort of producing such maps. For these reasons, national maps of this nature are generally not available nor are they considered very relevant for risk management. Rather, maps are prepared for specific geographic areas on the basis of the type of industrial hazard or hazards located there and the expected extent of their consequences.

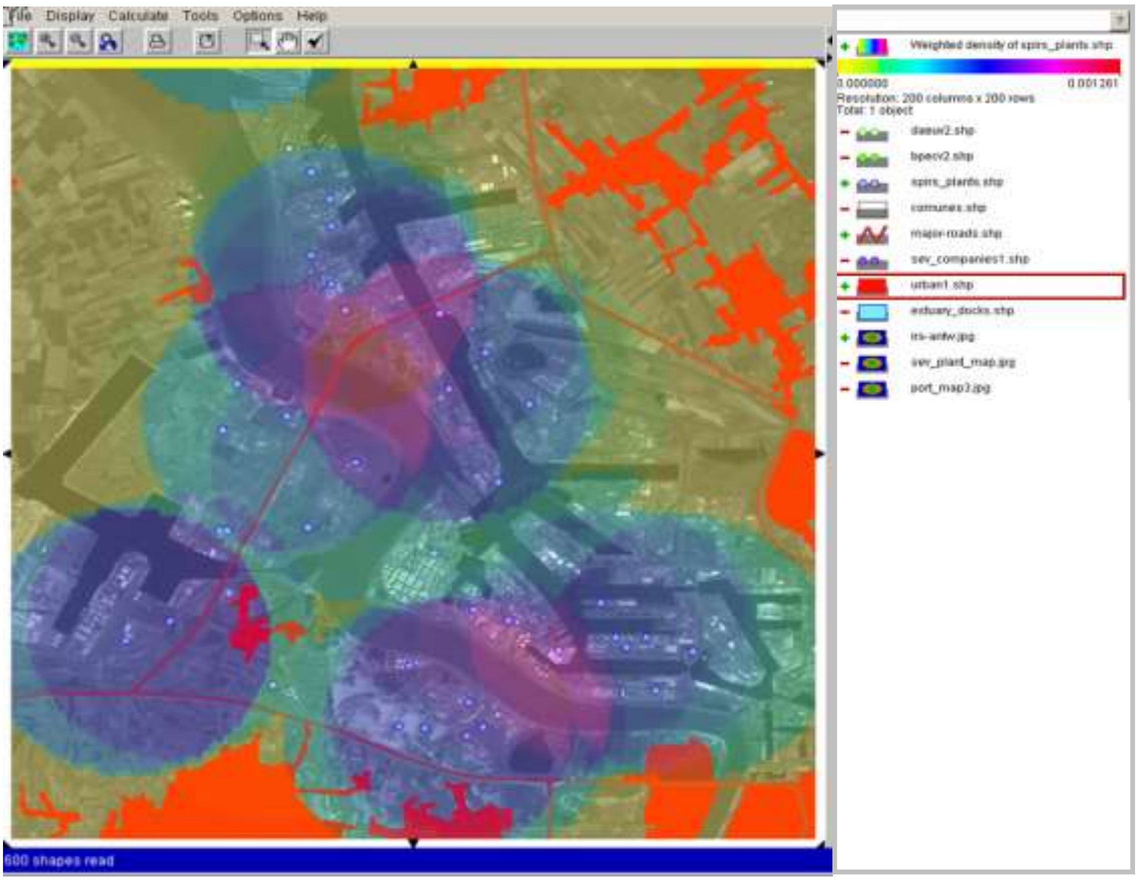

Figure 10. Risk Associated with Hazardous Installations Based on the SPIRS Hazard Index (Source: R. Peckham, EC-JRC-MAHB, 2005)

For the simplest types of industrial hazard maps, the name and location of establishments with hazardous substances may be considered sufficient. Additional dimensions such as types of activities, and types and quantities of substances present at these facilities might also be added. Although this mapping technique may appear simple, it can actually be a useful basis for the most basic type of industrial risk map, that is, one which relates the descriptive properties with accident probabilities.

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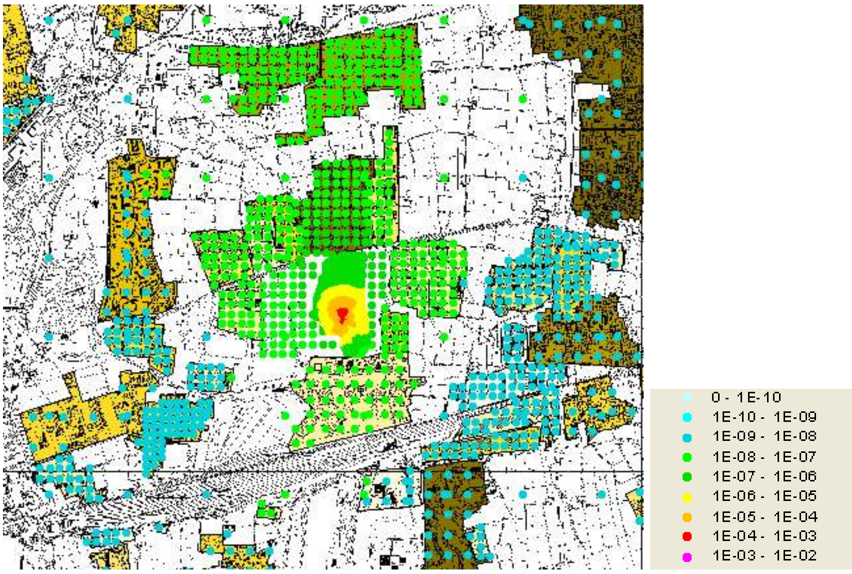
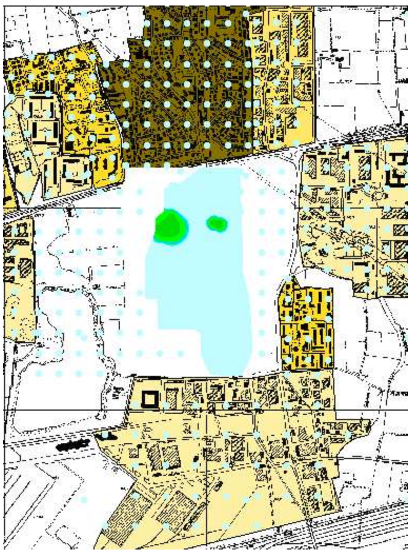
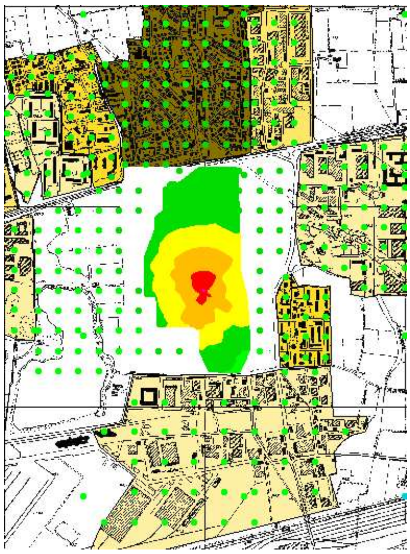
[27] Ibid., pp. 10-12

In contrast, the mapping of accident scenarios using risk assessment methodologies requires substantially more data, particularly if modelling of the physicochemical effects across a particular geographic area is involved. It is necessary to know the inventory of dangerous substances in industrial installations in a particular region, as well as their hazardous properties, and the types of processes and equipment at the establishment that are relevant to the handling and storage of these substances. Furthermore, precise information is needed regarding substances and process conditions, such as volatility, flammability, temperature, rate of loss of containment and typical weather conditions. Also, studies to estimate the failure frequency of process equipment involved may also be performed and incorporated into the analysis of potential effects.



a) Local risk of the BEQUAR plant: contribution by all risk sources





b) Contribution by Tank Wagon **c) Contribution by Ethanol Tanks**

Figure 11. Accident Scenario Maps from the Benchmark Exercise in Quantitative Area Risk Assessment in Central and Eastern European Countries (BEQUAR) 28

[28] Fabbri, L., Jirsa, P. and Contini, S. 2007. Benchmark Exercise in Quantitative Area Risk Assessment in Central and Eastern European Countries (BEQUAR). Final Report. European Commission. Joint Research Centre (Ispra, Italy). EUR 22169 EN.

From these data, risk maps may be obtained by combining the effects of potential accident scenarios with their predicted frequencies. Figure 10 and Figure 11 on the preceding pages are examples using the JRC's ARIPAR area risk assessment tool. The result is translated into curves depicting different levels of risk around the installation, allowing estimation of specific consequences through the calculation of exposed populations and natural resources inside these curves. There are several well-known sources for frequency data. Moreover, information on the causes and consequences of past accidents at the establishment or similar establishments can be used to predict the likelihood of similar accidents in the future.

4.7.4 The use of industrial risk mapping and assessment for land-use and emergency planning in the EU

There is considerable experience in the Member States in applying risk assessment and mapping techniques for implementation of Seveso II Directive obligations. Specifically, the potential consequences of different scenarios, as estimated within the risk assessment, and in particular in terms of residual risk, are of primary importance in the implementation of provisions within the Seveso II Directive related to land-use planning (Article 12) and emergency planning (various Articles). The Directive does not prescribe the methodologies that should be used to achieve compliance. While there is a strong desire for consistent approaches to Seveso implementation among the Member States, experience has shown that harmonisation of risk assessment approaches is neither feasible nor particular desirable. On the one hand, national approaches may differ considerably on the basis of different historic management and cultural perceptions of risk between countries and also because of the needs presented in particular local situations. For example, the role of land-use planning in risk management depends on its scope according to national legislation. In the traditional form of land use planning, it mainly would be a mitigation tool to reduce the extent of consequences. However, in many countries, it may be implemented in connection with a permit scheme with the possibility to impose technical conditions for new construction to reduce vulnerability. In this usage, it may also then be considered a prevention tool. Risk assessment for land-use planning around industrial establishments can be very sensitive because calculation of high potential risk may limit the resource value of land and in turn the profitability of proprietors and communities.

Just as importantly, different risk management objectives, e.g. land-use planning vs. emergency planning may often require different risk assessment approaches. To illustrate, as opposed to risk assessment for land-use planning, aimed at assisting with decisions about the allocation of land resources, risk assessments for emergency planning are aimed at ensuring proper preparation and response. These risk assessments can therefore afford to be more conservative than land-use planning risk assessments. Hence, many authorities will apply a different risk assessment and mapping approach for this purpose. Worst case estimates may in some cases be even desirable. Also, plans are only implemented if an accident occurs, in contrast with land-use planning where actions are taken and resources are allocated on the basis of potential risk. Logistics planning requires taking into account the practicalities of responding to specific types of emergencies in specific areas, for example, figuring out evacuation routes, the boundaries of zones where shelter-in-place might be applied, the location of firefighting stations, medical services, etc. In addition, some authorities are now also applying another kind of risk assessment method for what are being called "public information" zones, for identifying potential needs in preparation for a possible emergency and also once an emergency occurs.

However, as an alternative to EU harmonization of risk assessment approaches, Member States have collaborated in recent years on sharing the technical inputs to risk assessment,

such probabilistic data , parameter inputs (e.g., impact thresholds), and consequence analyses models.

4.7.5 Towards a comprehensive EU approach to risk mapping and risk assessment

It appears that many countries produce hazard maps but not necessarily risk maps identifying hazards in association with vulnerabilities. In addition JRC studies of industrial risk in EU countries show that there are significant differences across countries in the availability and quality of maps regarding industrial hazards. Although all countries tend to have data collection on industrial hazard establishments as well as pipeline networks, the typologies, detail, and units of classification of data may differ widely. In contrast, vulnerability maps associating the presence of hazards with, for example, population density or vulnerable objects (e.g., hospitals, schools) produced in many countries on a national scale in the past. With greater risk mapping and the advent of sophisticated digital mapping technologies, there may now be already a growing tendency to place more focus on risk mapping as opposed to simple hazard mapping.

On the other hand, many countries use risk assessments to create industrial risk maps but these are usually for local purposes, such as land-use and emergency planning. Industrial risk maps obtained from risk assessments of accident scenarios are similar to vulnerability maps in that they are based on a quantitative estimate of severity and frequency of potential consequences calculated for specific scenarios. The JRC's ARIPAR area risk assessment tool and the associated ADAM application for consequence analysis are examples of such programmes. The ARIPAR/ADAM suite of applications produces quantitative estimates of risks in localised areas for all risks present in the area connected with storage, process and transportation of dangerous substances.

On the other hand, it appears that although there are few methodologies available for risk mapping industrial risks over large areas, they are not particularly well developed or widely used. In any case there is no common tendency among countries to produce such maps or use any particular method. (What are often called "risk maps" are actually simple hazard identification maps only.) However, there seems to be growing interest and research in the area of generalized mapping for industrial risk and this trend could be motivation for consolidating the existing research and identifying a consensus on the most useful approaches. The JRC risk assessment tools (Rapid-N for Natech and ARIPAR/ADAM) provide a promising basis for such work.

Most EU and EEA countries require some industrial risk mapping based on such risk assessments to facilitate local land-use and emergency planning requirements. Methods used to achieve different objectives can also vary considerably. It is unlikely that harmonisation of risk assessment approaches across countries for management of industrial risks will ever be achieved. Across countries and even regions within countries, the methods used to calculate risk zones can be vastly different. Risk management objectives of different approaches also tend to foster development of risk assessment methodologies specific to those objectives. However, it is thought that, with continued collaboration among the Member States, on sharing of data and models on developing common tools for benchmarking and making data interoperable with different models, greater transparency in the methods used and the ensuing results can be achieved.

A point to note is that, even when countries are using and producing risks maps for generalized areas as well as local planning needs, much of the information is often not publicly available. In recent years concerns about the security of hazardous installations in the face of various threats (e.g., terrorism, chemical theft) has caused some countries to restrict access to such data. Any initiative to create a generalized risk map of Europe should take this into account.

4.8 Critical Infrastructure Protection

4.8.1 Introduction

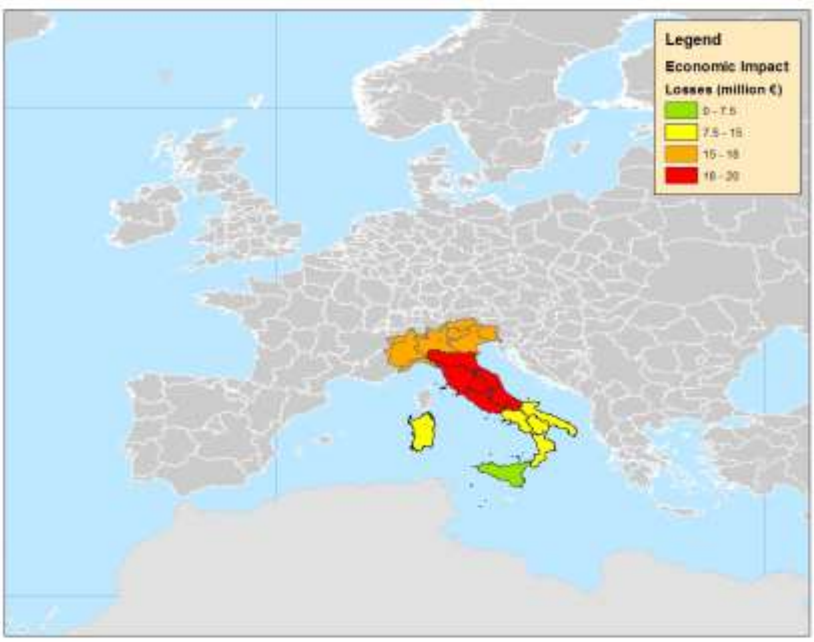
Critical Infrastructure Protection at European level is implemented through the EPCIP (European Programme for Critical Infrastructure Protection). EPCIP has several elements among which a legislative one, the Council Directive 2008/114/EC on the "Identification and designation of European Critical Infrastructures and the assessment of the need to improve their protection".

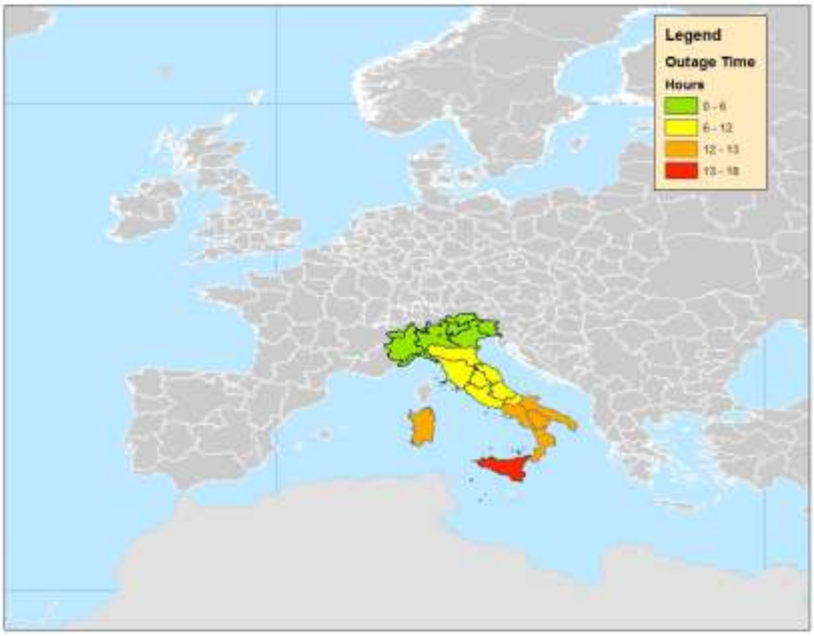
The elements of risk assessment and the corresponding methodologies are explicitly mentioned in the Directive text. This demonstrates the importance of risk assessment for critical infrastructures at European level. Actually no harmonized methodology exists and Member States are following their own respective methodologies making the comparison and communication of risks a cumbersome process.

Risk assessment for critical infrastructures is rather complex. This is mainly due to the nature of modern critical infrastructures (distributed networks of interconnected infrastructures), the variability of threats and vulnerabilities and the cascading effects that may develop in a wide range of infrastructures. Thus there are important challenges to overcome towards establishing harmonized risk assessment methodologies for critical infrastructures at European level. JRC is working towards this direction and several elements are already in place.

4.8.2 Risk map of Europe

As mentioned before no harmonized risk assessment methodologies exist at European level for the assessment of critical infrastructures. In this effort JRC has developed several tools and among these the capacity to evaluate the economic impact of critical infrastructure disruption. An application of this analysis framework has taken place for the Italian blackout in 2003. Using Input-output modelling techniques and engineering models for the disruption propagation and integrating everything over a GIS platform it is possible to create economic impact maps of critical infrastructure disruption at national level as well as at regional level. The association of impact with probabilities of disruptive events can lead to economic risk maps due to critical infrastructure disruption.





4.8.3 Tabular data by country

At the moment no specific database exists for critical infrastructures at European level. Several databases can be used in order to extract data for critical infrastructures risk assessments but no systematic harmonized recording of incidents and impact currently exists.

JRC aims to bridge this gap in the near future by trying to establish databases at European level on the disruption of critical infrastructures, the associated impact and the interdependencies that have been revealed during an event that may have not been initially foreseen.

4.8.4 Specific risk assessments

The approach implemented by JRC in order to build risk assessment methodologies has several steps. The first step is to evaluate the impact of hazards (natural, man-made, cyber, terrorist attacks) to assets of critical infrastructures. The next step is the assessment of cascading effects within this infrastructure, thus passing from the asset level assessment to the systems assessment level. Then the cascading effects to other infrastructures due to interdependencies are analysed. The final step is the evaluation of the economic impact of CI disruptions. Although this may not be a Risk Assessment but rather an Impact Assessment approach, the association of threat probabilities brings this methodology closer to a pure risk assessment.

Several tools are developed or are under development in JRC for the assessment of impact on assets of critical infrastructures due to variety of hazards and more specifically for natural hazards (e.g. RAPID-N), the cascading effects within a critical infrastructure, between interdependent critical infrastructures and the economic impact.

Currently a GIS-based platform (CIR^2, **C**ritical **I**nfrastructure **R**isk and **R**esilience) is under development for the analysis of complex networked infrastructures. The concept behind this platform is to visualize critical infrastructures, provide an analysis of the vulnerable elements, model the propagation of a failure within an infrastructure due to an asset or multiple assets disruption, model the disruption propagation to interdependent infrastructures and finally evaluate the economic impact. In terms of modelling tools, several elements exist and

currently an integration process is taking place for bringing everything together within a GIS environment.

In addition it is foreseen to complement this with a documentation and communication layer over which the users of the system will be able to exchange information, share analyses results, upload technical documents, etc.

4.8.5 Methodological notes

This new platform aims to bring a different concept for the analysis of critical infrastructures disruption. It will offer a suite of models, and modules in order for the user to be able to upload his/her own data, models and perform the analysis. It actually enables the user to perform analyses on critical infrastructures in an easy and user-friendly way. CIR^2 is not sectoral, it will be possible to use it for various sectors of critical infrastructures.

4.8.6 Towards a comprehensive EU risk assessment

Clearly one of the identified gaps in the domain of critical infrastructure protection is the lack of common methodologies for risk evaluation and risk reporting that requires databases at EU level for threats, vulnerabilities, interdependencies and impact of critical infrastructures disruption. The interdependencies element and also the evolution of cascading effects during a disaster are particularly important and are currently missing. In terms of methodologies there are many elements in place that need to be integrated. JRC aims to integrate all these towards a harmonized risk assessment methodology and the development of the corresponding tools.

4.8.7 Contribution from ERNCIP

As part of European Programme of Critical Infrastructure Protection (EPCIP),[29] the European Reference Network for Critical Infrastructure Protection (ERNCIP),[30] funded by DG HOME and implemented by DG JRC, IPSC, Ispra, is focusing on the technological security solutions for critical infrastructure protection (CIP).

The EPCIP Directive focuses only on European critical infrastructures (CI) and concentrates on the energy and transport sectors.[31] ERNCIP covers all EU CI sectors and deals also with national critical infrastructures on an all-hazard basis. The mission of ERNCIP is to "*To foster the emergence of innovative, qualified, efficient and competitive security solutions, through networking of European experimental capabilities".* In order to achieve its mission ERNCIP puts its efforts in maintaining an online inventory of experimental capabilities in Europe and in developing a network of experts to collect good test practices and to promote those to become the basis of joint European standards.

Member States have identified some priority CIP areas of concern for ERNCIP to address at the EU level. Currently these ERNCIP thematic areas cover a wide range of subjects, such as aviation security, non-aviation explosives, structural resistance to explosives and seismic risks, biological and chemical risks in drinking water, radiological risks, biometrics, and video surveillance, smart grids and industrial automated control systems, focusing on standardization of testing methodologies of security solutions in these areas.

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29 See:http://ec.europa.eu/dgs/home-affairs/what-we-do/policies/crisis-and-terrorism/critical-infrastructure/index_en.htm

30 See: http://ipsc.jrc.ec.europa.eu/index.php/ERNCIP/688/0/

31 "'European critical infrastructure' or 'ECI' means critical infrastructure located in Member States the disruption or destruction of which would have a significant impact on at least two Member States." COUNCIL DIRECTIVE 2008/114/EC of 8 December 2008 on the identification and designation of European critical infrastructures and the assessment of the need to improve their protection, to be found at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:345:0075:0082:EN:PDF

In the Commission Staff Working Document from June 2012, 32 it is envisaged that in the revised EPCIP the first step would be the assessment of "criticalities" (risks) of the field, which would mean to identify, assess and agree upon the criticalities jointly with Member States and operators.

CI are vulnerable to malicious attack and other man-made malfunctions, technological failures, natural disasters and hazards, and their combinations. One of the vulnerabilities is the interdependencies between CI and the resulting cascading effects of possible CI failure.

The EC, in particular the JRC, is playing a supporting and facilitating role by developing guidelines, methodologies, and other tools that will allow an overall assessment of dependencies and criticalities. The overview of criticalities and dependencies will remain with Member States and operators.

While ERNCIP does not directly identify and deal with the criticalities themselves, it may be used to identify the gaps in the technological security solutions used in CIP, as well as gaps in their use in operational environment.

ERNCIP could be used to both provide technical assessment of the criticalities of CI and propose activity on EU-wide standards to help reduce the risks. Furthermore, ERNCIP has more than 250 active expert stakeholders, including governmental competent authorities and regulatory agencies, CI operators and owners, security solution manufacturers and vendors, and experimental facilities and laboratories. This is an important pool of knowledge to be used in future initiatives, including assessment of criticalities and risks existing in the field of CI.

In the framework of a Civil Protection exercise involving CI the existing ERNCIP organisation structure could be used to quickly establish EU-level groups of experts to technically assess components and methods used and stressed throughout the exercises for their appropriateness. This will allow the experts to draw new testing standards for failing components and therefore improve the EU and international standards in security. ERNCIP will contribute in understanding not only if components have failed but also why they have failed giving important input to the Operators on how to improve them. At the same time the experimental facilities and manufacturers involved in the ERNCIP network will have the opportunity to develop and promote new and innovative components and methods, contributing to EU's economic growth.

[32] Commission Staff Working Document on the Review of the European Programme for Critical Infrastructure Protection (EPCIP) Brussels, 22.6.2012, SWD(2012) 190 final, to be found at http://ec.europa.eu/dgs/home-affairs/pdf/policies/crisis_and_terrorism/epcip_swd_2012_190_final.pdf

4.9 Emerging risks and other hazards

JRC has expertise in other areas, but does not have data readily available for an EU-wide risk assessment. In future versions of this report, additional information may be included. The risk areas of interest to ECHO for which JRC did not contribute in this report include:

- **Space weather:** Work is on-going at the JRC to assess the risks of space-weather impact on ground- and space-based infrastructures with the aim to better understand the potential consequences on society.

- **Nuclear accidents**: JRC nuclear unit may have some follow-up analysis to the stress tests and scenarios for the economic and environmental impact in case of an accident.

- **Pandemic and health emergencies**: No data is currently available at JRC.

- **Climate change impact**: climate scenarios on how climate change would affect the natural hazards, including heat waves, sea level rise, storm surge, and other emerging risks

- **Urban characterization**: potential exposure datasets, maps of human settlement of Europe from the Global Human Settlement Layer (GHSL)

5 Conclusion

This technical report is aimed to provide a description of the available knowledge at JRC relevant for EU risk assessment policy. It summarizes the projects, systems, methodologies and datasets described in a bilateral meeting between ECHO.A.3 and JRC on 23 October 2012 in Ispra, Italy. Given the short deadline, the authors have summarized available data and have not conducted new risk assessments. For some hazard types, JRC has the capability to perform risk assessments provided a dedicated project is defined.

For earthquakes, the risk is relatively well known at European level, although local risk assessments are necessary to identify particular risks and secondary effects. The countries most at risk (without considering vulnerability and coping capacity measures) are Croatia, Romania, Greece, Bulgaria, and Italy. Similarly, the cities most at risk are Zagreb (Croatia), Brasov, Galati, Bacau, Ploiesti, Iasi (Romania), Thessaloniki (Greece), Sofia, Plovdiv (Bulgaria), and Messina (Italy).

For tsunamis, the risk associated with tsunamogenic earthquakes is known at the same level as for earthquakes. Local risk assessments are necessary to identify particular risks related to high exposure (e.g. seasonal tourist activity). The Mediterranean and Black Sea countries are exposed to tsunami hazards, but the risk has not been qualified or quantified yet (Greece, Italy, Portugal, France, Spain, Cyprus, the Balkans, Bulgaria, and Romania).

For floods, the JRC produced flood hazard and risk maps at a spatial scale of 100m resolution which provide a harmonised, regional overview on flood hazard and risks across Europe. These complement the higher precision national information that is provided by the Member States for the Flood Risk management plans under the Flood Directive. The implementation timetable of the Directive foresees that flood hazard and risk maps are delivered by the end of 2013. The final Flood Risk Management plans should be submitted by the end of 2015. The information contained in these risk maps and management plans can be useful for prevention measures including the EU risk overview.

For forest fires, most of the damages are concentrated in just 5 EU Mediterranean countries: Portugal, Spain, France, Italy and Greece. A EU forest fire risk assessment should build on the work and collaboration already established between the Member States and the EC in the context of the European Forest Fires Information System (EFFIS). This follows the agreements already existing in the area of forest fires for the further development of EFFIS and the Council Conclusions of 2010 on forest fire prevention in the EU.

Regions with a moderate or high drought hazard are predominantly located in the Mediterranean region, especially the Iberian Peninsula, southern France, parts of Italy and Greece, and Cyprus. Central Europe, UK and Scandinavia are characterized by a low or very low hazard. The Carpathian Region, including large parts of Hungary and Romania, are among the regions at highest drought hazard over the last 20 years. Drought risk has not been assessed yet. The necessary data on societal vulnerability need to be collected and analysed.

For Natech risks, hardly any risk maps are available within the EU MS. Where existing, Natech risk maps simply overlay natural and technological hazards without considering site-specific features or the interaction of hazards. The need for a systematic Natech risk-mapping methodology is therefore evident. Consequently, the JRC has developed the web-based Natech risk analysis and mapping tool RAPID-N which identifies Natech -prone areas and analyses and visualises Natech risk.

For industrial risks (including Natech) assessment methodologies vary across the Member States, ranging from fully probabilistic to deterministic approaches and from fully quantitative to only qualitative. Prescription and harmonisation of risk assessment methodologies has never been achieved because of differences in safety cultures. However, EU level guidance for risk assessment could be instrumental in ensuring a minimum comparability of results. This guidance could, for instance, define the necessary components, formats and data sources for input to the risk assessment as well as a common format for risk assessment outputs. Such guidance could build on existing JRC collaboration with government, industry and academia in support of Natech and industrial risk in general.

Furthermore, few methodologies are available for the mapping of industrial risks over large areas. Although there is no common tendency among countries to produce such maps or use any particular method there seems to be growing interest and research in the area of generalized mapping for industrial risk and this trend could be motivation for consolidating the existing research and identifying a consensus on the most useful approaches. The JRC risk assessment and mapping tools (RAPID-N and ARIPAR/ADAM) provide a promising basis for such work.

European Commission

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Abstract

In response to a request by ECHO.A.3, the Joint Research Centre (JRC) collected a short overview of available scientific data and methods for risk assessment in Europe. The JRC has a long standing research programme in monitoring, modelling and assessing risk for various hazard types, including natural, human and combinations. While several Units are active in this area, it is not always an objective to create or collect data on hazards and risks in a pan-European database. More often, Units work on methodologies or underlying research. However, in support of ECHO's role in EU Risk Assessment, JRC compiled the available information from various Units into a technical report for ECHO.A.3, which will serve to have baseline data on risks in Europe. If relevant, this may also be the basis for defining specific projects with JRC to elaborate further on European wide risk assessments.

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As the Commission's in-house science service, the Joint Research Centre's mission is to provide EU policies with independent, evidence-based scientific and technical support throughout the whole policy cycle.

Working in close cooperation with policy Directorates-General, the JRC addresses key societal challenges while stimulating innovation through developing new standards, methods and tools, and sharing and transferring its know-how to the Member States and international community.

Key policy areas include: environment and climate change; energy and transport; agriculture and food security; health and consumer protection; information society and digital agenda; safety and security including nuclear; all supported through a cross-cutting and multi-disciplinary approach.

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