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Inspire Policy Making with Territorial Evidence

APPLIED RESEARCH //

ESPON-TITAN Territorial Impacts of Natural Disasters

Final Report

Applied Research // June 2021

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Abbreviations

CBA	Cost-benefit analysis
CCA	Climate Change Adaptation
DDM	Damage Distribution Matrix
DRM	Disaster Risk Management
DRMKC	Disaster Risk Management Knowledge Centre
EC	European Commission
EEA	European Environment Agency
EIA	Environmental Impact Assessment
EM-DAT	Emergency Events Database provided by Centre for Research on the Epidemiology of Disasters
ESPON	European Territorial Observatory Network
ETC	European Territorial Cooperation
EU	European Union
FRMD	Flood Risk Management Directive
FBS	Financial and Business Services
GDP	Gross Domestic Product
GRETA	GReen infrastructure: Enhancing biodiversity and ecosysTem services for territoriAl development
GVA	Gross Value Added
I/O	Input-Output
IPCC	Intergovernmental Panel on Climate Change
JRC	Joint Research Centre
NATECHS	Natural-technical hazards
NRA	National Risk Assessment
NUTS	Nomenclature of Territorial Units for Statistics
PCA	Principal Component Analysis
PR	Policy Recommendation
SCGE model	Spatial Computable General Equilibrium Model
SEA	Strategic Environmental Assessment
SPI	Standardized Precipitation Index
UN	United Nations
UNDRR	United Nations Office for Disaster Risk Reduction
UNISDR	United Nations International Strategy for Disaster Reduction
WFD	Water Framework Directive
WISC	Windstorm Information Service
WMO	World Meteorological Organization
WRTAFIC	Wholesale, Retail, Transport, Accommodation & Food services, Information and Communication

Glossary

Adaptive capacity: The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences (IPCC, 2014).

Climate Change Adaptation (CCA): In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects (IPCC, 2014).

Coping capacity:
resources, to manage adverse conditions, risk or disasters. The capacity to cope requires continuing awareness, resources and good management, both in normal times as well as during disasters or adverse conditions. Coping capacities contribute to the reduction of disaster risks (UNISDR: UN, 2009, 2016).

Coping capacity: skills and
resources, to manage adverse conditions, risk or disasters. The capacity to cope requires continuing awareness, resources and good management, both in normal times as well as during disasters or adverse conditions. Coping capacities contribute to the reduction of disaster risks (UNISDR: UN, 2009).

Damage: Total or partial destruction of physical assets existing in the affected area[1].

Damage function: Damage functions are used to translate the magnitude of a (natural) hazard into a quantifiable damage on infrastructure, economic assets, ecosystems, etc.

Damage Distribution Matrix (DDM): DDM is a matrix in which each element (one number in the matrix) represents the distribution (or weight) of the total costs among the affected NUTS3 areas and among the five capital stocks for each NUTS3 region, i.e., it gives you the weight of the cost per capital stock for a specific event level.

Disaster:
hazardous events interacting with conditions of exposure and vulnerability, leading to human, material,

Disaster impacts: It is the total effect, including negative effects (e.g., economic losses) and positive effects (e.g., economic gains), of a hazardous event or a disaster. The term includes economic, human and environmental impacts, and may include death, injuries, disease and other negative effects on human physical, mental and social well-being (UN, 2016).

Disaster risk:

(UNISDR: UN, 2009).

Disaster risk assessment: "A qualitative or quantitative approach to determine the nature and extent of disaster risk by analysing potential hazards and evaluating existing conditions of exposure and vulnerability that together could harm people, property, services, livelihoods and the environment on which they depend" (UNISDR: UN, 2009).

Disaster risk information: "Comprehensive information on all dimensions of disaster risk, including hazards, exposure, vulnerability and capacity, related to persons, communities, organizations and countries and their assets" (UNISDR: UN, 2009).

Disaster Risk Management (DRM): Disaster risk management is the application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk and manage residual risk, contributing to the strengthening of resilience and reduction of disaster losses (UN, 2016).

Economic Loss: Monetary value of total or partial destruction of physical assets existing in the affected area[1].

Exposure: "The situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas" (UNISDR: UN, 2009).

Hazard: "A process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation." (UNDRR, 2018).

Impact pathway: It is a conceptual model that will define the link between a natural hazard and its direct and indirect economic impacts.

Natural hazard: use loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation" (UNISDR: UN, 2009).

Risk
vulnerability of the system or element exposed (Birkmann, 2013). Risk is estimated by combining the probability of a hazard occurrence, and the potential scale of consequences (e.g., injury, damage, and loss) that would arise if the event strikes society or exposed elements".

Risk governance: The system of institutions, mechanisms, policy and legal frameworks and other arrangements to guide, coordinate and oversee disaster risk reduction and related areas of policy (UN, 2016).

Sensitivity: The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change. The effect may be direct or indirect (Adapted from IPCC, 2014).

Vulnerability (risk concept): "The conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards" (UNISDR: UN, 2009, 2016).

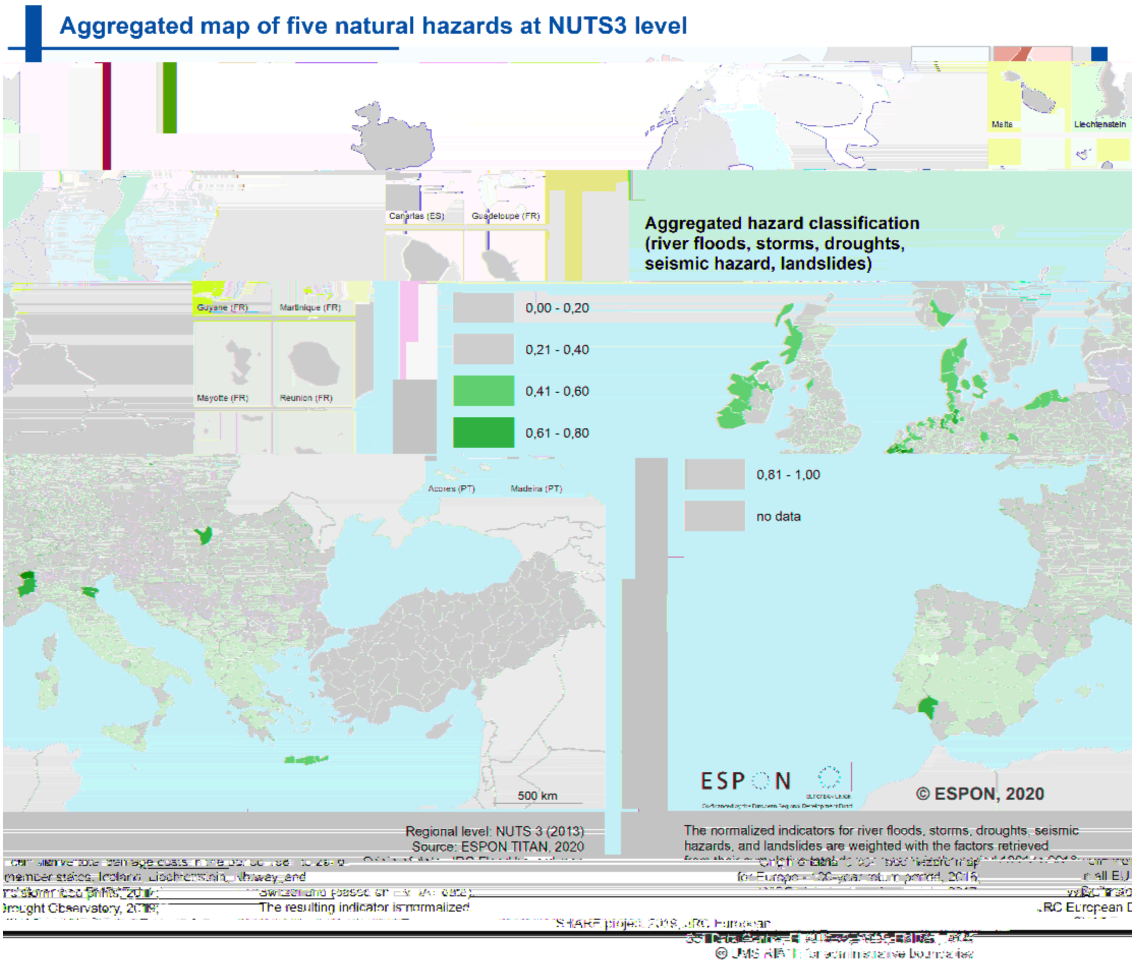
Vulnerability (climate change vulnerability concept): The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (IPCC, 2014).

[1] https://www.unisdr.org/files/45462_backgoundpaperonterminologyaugust20.pdf

Executive summary

ESPON-TITAN Territorial Impact of Natural Hazards, uses innovative approaches and methodologies, to provide analysis of the distribution and territorial patterns of the impacts of the natural hazards across Europe both direct and indirect , as place-based evidence to support the identification of the most vulnerable regions. Moreover, the project identifies existing effective measures on Disaster Risk Management (DRM) and Climate Change Adaptation (CCA) instruments at different policy levels, that should be mainstreamed into integrated spatial planning and territorial development policies.

In ESPON-TITAN, four main natural hazards, which most hardly affect the European territory, are analysed, to be mentioned: river floods, windstorms, drought, and earthquakes. The distribution of aggregated hazards (Map 1.1) is based on the combination of normalised hazard indexes weighted with their cumulative damage costs in the period 1981-2010. Floods and windstorms have contributed to nearly 76% of the damage and losses, followed by droughts and earthquakes (24% both). On the aggregated hazard map, the high intensity of windstorms is visible in exposed coasts, coinciding in many cases with low-lying flood prone areas. High aggregated hazard values are also resulting from the combination of other important hazards, such as floods and droughts (e.g. Eastern Romania). Some considerations regarding the interpretation of this map are that (i) the map do not assess flood protection measures and therefore, also do not assess the effective risk, (ii) droughts are represented in NUTS0, which may partially lead to strong contrasts at national borders, and (iii) the weighting of the aggregation is derived only from economic damage and losses (not including human fatalities or damage and losses that cannot be expressed in monetary values). (see Section 2.1.1 for a detailed description and analysis).

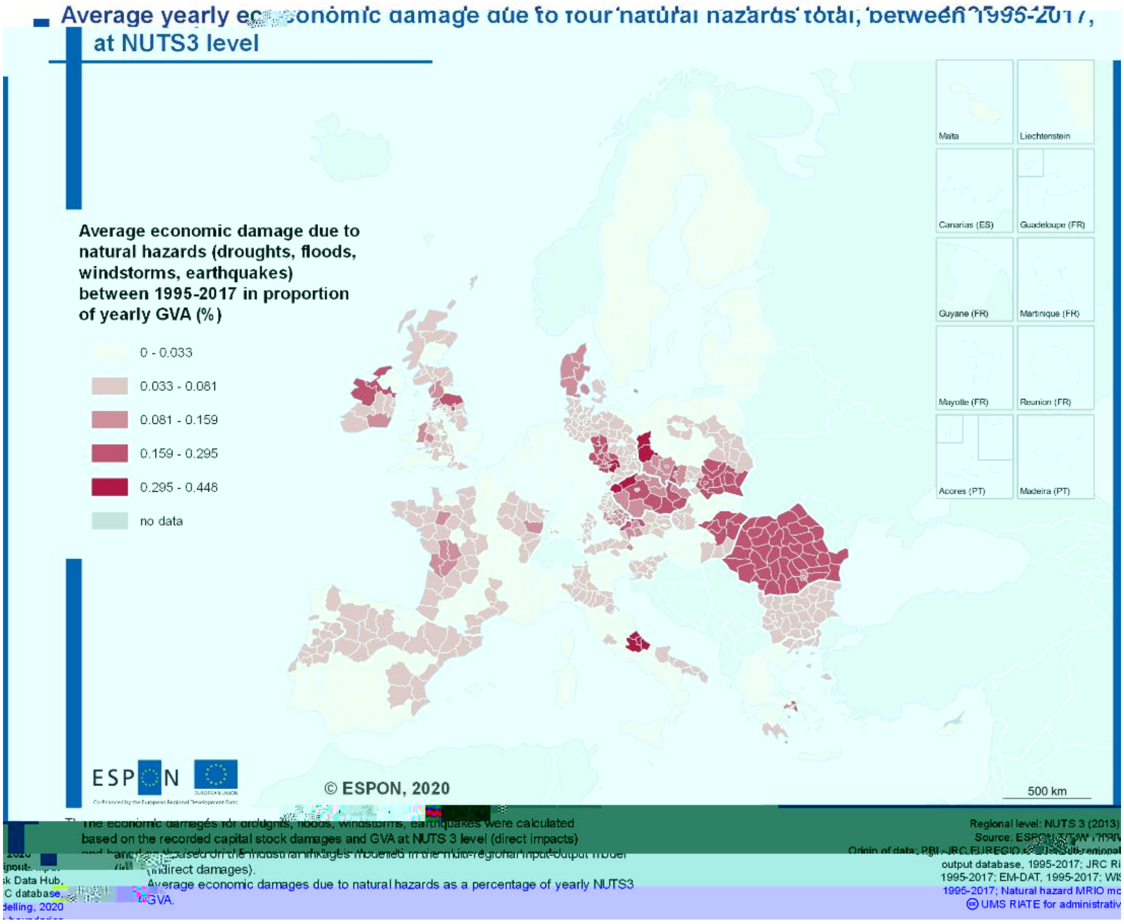


Map 1.1 Aggregated hazard map

Innovative methodologies have been developed to deliver the analysis of economic impacts and territorial vulnerability assessment. The approach used to calculate the economic impacts is based on self-developed damage-distribution matrices and Input-Output (I/O) tables to measure, in a monetised value, how the territory is affected by different types of disasters. The analysis revealed that indirect economic impacts induced, in specific regions, by a disruption of economic activities in other ones, tend to be almost as large as direct impacts. Direct impacts are those damage and losses resulting from a natural hazards directly affecting a region (geographically happening there, and damaging the capital stock of the region), while indirect impacts are resulting from the analysis of I/O tables and the derived linkages of economic sectors across regions and countries. The ratio of indirect impacts to direct impacts falls between 60% and 90% across all the period analysed.

The spatial distribution of the economic impacts (based on data of the period 1995-2017) indicates that Central, Southern and Eastern European countries tend to be relatively more affected by these natural hazards, in economic terms, than most of the rest of the European territory. This implies that those countries are recommended to develop place-based measures to reduce the effects of these events in the future (see Section 3.1 for detailed description and analysis).

Map 1.2 shows yearly average relative economic damage and losses (as the ratio of economic output drop and the GVA) due to the four natural hazard types, for the period 1995-2017 at the NUTS3 level for the ESPON area (where data was available). Besides, Central, Southern and Eastern countries, certain NUTS3 areas of the UK and Ireland, Denmark, France and Spain (mostly coastal) are also heavily affected in economic terms by one or more natural hazard types.

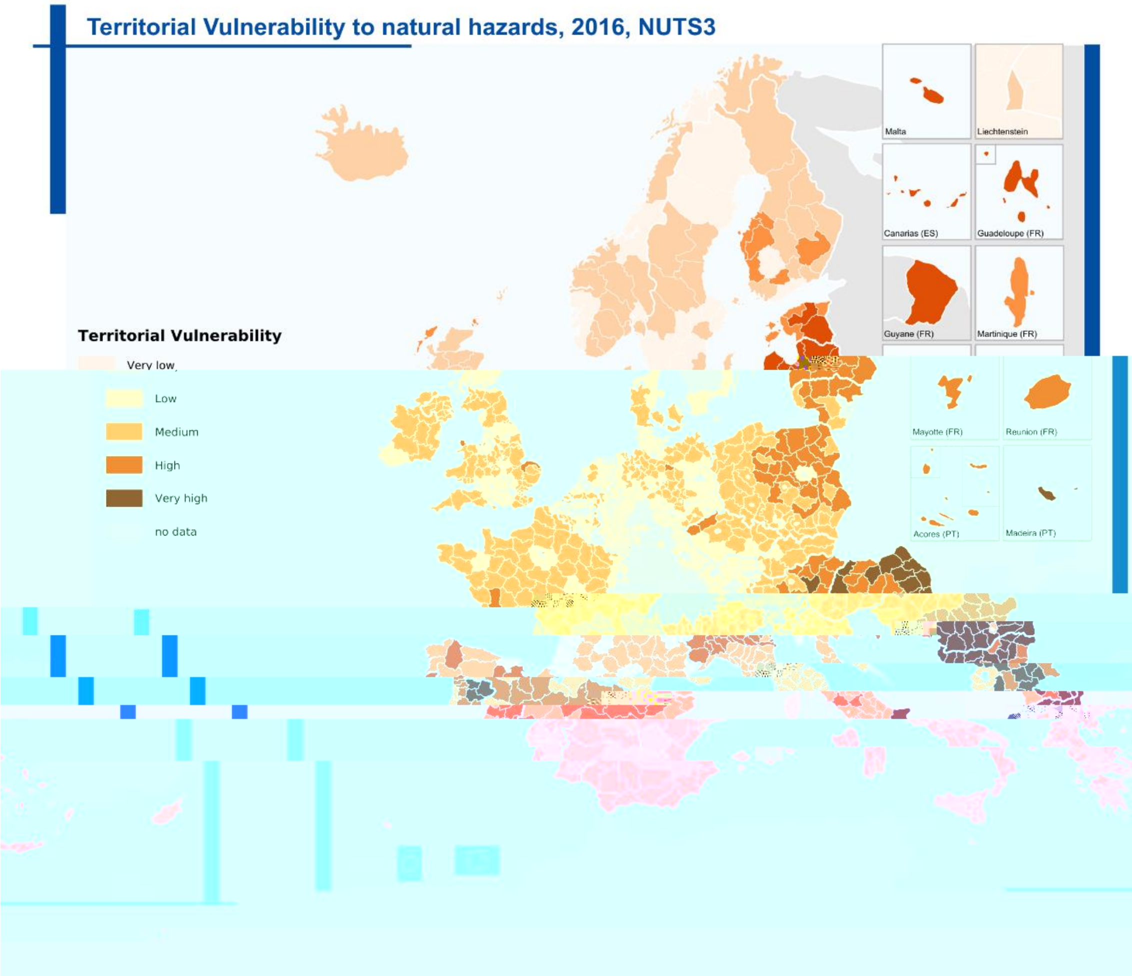


Map 1.2 Economic damage due to the four natural hazard types, yearly average 1995-2017, at NUTS3 level

The economic impact analysis has also included a pilot local analysis with a detailed methodology in two of the eight ESPON-TITAN case studies (namely Nouvelle-Aquitaine and Prague). In those the results of the global methodology (based on top-down information) was compared with the results of the local methodology (based on bottom-up information). The comparison showed that the local methodology evidenced higher damage costs per event, due the inclusion of detailed information of actual incurred events in the region.

The local methodology also allowed a deeper understanding of key drivers of economic impacts through qualitative research. It is therefore recommended that the global methodology should serve a pre-screening purpose, in the sense that it should be best used to sense-check where further analysis is needed (i.e. events with initially high damages reported or events that have heavily affected certain sectors), for targeted place-based policy development.

Additionally, a territorial vulnerability assessment was developed at a European level. The methodology is based on principal component analysis (PCA), considering indicators related to susceptibility and coping capacity. New indicators were included in comparison to previous projects (e.g.: ESPON-CLIMATE[2] or RESIN[3]), such as governance, social capital, gender, risk perception, among others. Map 1.3 shows territorial patterns of the vulnerability assessment and clearly shows that Easter and South Europe areas are the most vulnerable. Beyond the territorial distribution of different levels of vulnerability, results were also interpreted in relative terms to the exposed population, showing that 22% of European population lives in territories with high vulnerability levels, especially in Romania, Italy, Bulgaria and Greece (see Section 5.1 for detailed description and analysis).



Map 1.3 Territorial vulnerability to natural hazards, 2016, NUTS3

[2] ESPON-CLIMATE Project, Climate Change and Territorial Effects on Regions and Local Economies in Europe. ESPON (https://www.espon.eu/climate).
[3] RESIN Project, Climate Resilient Cities and Infrastructures. H2020 (https://resin-cities.eu/home/our-aim/).

ESPON-TITAN validated the abovementioned findings through eight representative case studies (Andalusia-ES, Nouvelle-Aquitaine-FR, Rotterdam-NL, Po river basin-IT, City of Pori-FI, Prague-CZ, Dresden region-DE and Alpine Region) with a multiscale perspective, that encompass transnational, national, regional and local scales, with differentiated characteristics e.g. special consideration to one particular type of hazards, existence of operational cooperation and collaboration between involved entities, etc. Good practices were distilled from the case studies analysis, as a supporting pillar of the final policy recommendations elaborated in ESPON-TITAN.

Besides stakeholders from the case studies, a wider range of external experts, institutions and networks (EEA European Environment Agency, JRC Joint Research Centre, National and Regional administration representatives, ESPON support team) were engaged in different ESPON-TITAN activities, sharing experiences and insights about the methodology and the results. The involvement of actors from different scale in the discussions (European, cross-border, national, regional and local), as well as from a wide range of backgrounds, has led to a rich variety of perspectives and contributions. Experienced institutions, such as EEA and JRC, have been part of the debate on methodological approaches and results at different stages of the development of the project, giving a valuable input and guaranteeing that the development in place is coherent and perfectly aligned with a European transversal vision on disaster risk and vulnerability matters. Existing ESPON project results have also given some insights and base for comparison and decision on the definitive approach to follow, as for example, ESPON-HAZARDS[4], ESPON-CLIMATE and ESPON-GRETA[5] GReen infrastructure: Enhancing biodiversity and ecosysTem services for territoriAl development.

The results of ESPON-TITAN project provide insights that may support recommendations on how governments should cooperate to ensure the efficiency and coordination of adaptation and mitigation measures related to disasters, at European, national, regional and local levels. The main outcomes are translated into policy recommendations, framing the political debate on how the territorial impacts of natural hazards affect the territory and what the consequences of having coherent policies in place may be, at the same time reinforcing the need of integrating DRM and CCA strategies into territorial planning instruments.

The ESPON-TITAN policy recommendations are structured around the different stages of the policy process (i.e. problem identification and agenda setting, formulation and adoption, implementation, and evaluation) and compiled in three groups:

- **Policy recommendations related to economic impacts, focused on methods and data:** (i) harmonisation of concepts and methods for risk assessment and evaluation and (ii) development of a framework for the collection of the necessary data at the local level across Member States/authorities (sections 8.1. and 8.2);
- **Policy recommendation related to the connection between economic losses and appropriate DRM and CCA measures:** (i) proposition of DRM and CCA measures and plans accounting for the total economic impacts of the occurring natural hazards, including both direct and indirect losses as well as risk aversion factors (section 8.3);
- **Policy recommendations related to the improvement of DRM and CCA practices in terms of funding, cooperation and legislation:** (i) focused promotion of a pro-active and prevention-oriented design of EU funding instruments in combination with quality objectives regarding funding of reconstruction, (ii) development of cooperation structures between regions, cities and local governments but also between different experts based on a balanced set of formal and informal elements and (iii) systematically assessment of EU directives for their potential to support DRM and CCA issues (sections 8.3, 8.4 and 8.5).

[4] ESPON-HAZARDS Project, Spatial Effects o Natural and Technological Hazards. ESPON Project 1.3.1. (https://www.espon.eu/programme/projects/espon-2006/thematic-projects/spatial-effects-natural-and-technological-hazards).

[5] ESPON-GRETA Project, Green infrastructure: Enhancing biodiversity and ecosystem services for territorial development. ESPON (https://www.espon.eu/green-infrastructure).

In summary, this Final Report builds on a number of key outputs delivered over the study period. These include:

- identification of territorial patterns of natural hazards (Chapter 2 / Annex 1);
- assessment of direct and economic impacts at both global and local levels (Chapters 3 and 4 / Annex 2);
- development of a territorial vulnerability index (Chapter 5 / Annex 3);
- elaboration of an extensive literature review and further analysis of DRM and CCA strategies and related good practices (Chapter 6 / Annex 4);
- illustration of findings through regional case studies (Chapter 7 / Annex 5);
- formulation of policy pathways for the future (Chapter 8 and 9 / Annex 6).

1 Introduction

ESPON-TITAN: Territorial Impacts of Natural Disasters -TITAN) aims to analyse the distribution and territorial patterns of natural hazards and their potential economic impacts in Europe. Those evidences are generated throughout a direct and indirect economic analysis, completed with an indicator-based vulnerability assessment. Based on those outputs, the project also explores good practices of Disaster Risk Management (DRM) and Climate Change Adaptation (CCA) at different territorial levels, and deepen on their integration into spatial planning and territorial development policies. By considering a multiscale perspective, ESPON-TITAN supports those findings through eight representative case studies that encompass trans-national, national, regional and local scales.

The conclusions are translated into policy recommendations for better considering territorial vulnerability and economic impacts of natural hazards into both DRM and CCA strategies, as part of an integrated place-based spatial development planning.

1.1 ESPON-TITAN conceptual framework

Risk analysis, commonly based on events probability of occurrence and related consequences, has evolved notably during the last years, with important contributions from the disaster risk management and climate change communities. There is currently an alignment between the DRM and CCA communities, having a common understanding of risk. Being a global consensus that **risk**

approach risk is mainly based on probability of occurrence, whereas in the CCA approach is focused in future scenario analysis.

Hazards are natural; disasters are not (UNISDR, 2010), i.e. a hazard cannot be prevented, while disasters can. Earthquakes, droughts, floods, storms and landslides, among others, are natural hazards; they may lead to deaths and damages i.e. disasters because of human acts of omission and commission, rather than the act of nature (UNISDR, 2010). There are an increasing number of documents and publications that reinforce that, and even a growing online campaign that advocates this idea under the slogan #NoNaturalDisasters[6]. In some cases, however (as in the title of this project/report that could not be changed due to legal reasons), this term may, inaccurately, still appear even in official documents as a synonym

until some years ago it was widely used.

Accordingly, a **natural hazard** is a physical event, process or phenomenon that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation (UNDRR, 2016, 2019), being characterised by its location, probability of occurrence, magnitude, geometry, frequency and other characteristics (Birkmann, 2013), as intensity and duration. A natural hazard is a geological or hydrometeorological, extreme event that belongs to normal natural occurrences.

Other concepts and analytical approaches as impact assessment, loss estimation or damage functions are often used to better understand and quantify the consequences of a given hazard or extreme event, contributing to risk analysis.

In this framework, a **disaster**
scale due to hazardous events interacting with conditions of exposure and vulnerability, leading to human,
(UNISDR: UN, 2009, 2016), above a certain threshold of impact which is context-specific. Therefore, **disaster risk**
destroyed or damaged assets which could occur to a system, society or a community in a specific period of

(UNDRR, 2018).

[6] https://www.nonaturaldisasters.com

Regarding vulnerability, the DRM and CCA communities use slightly different but compatible approaches for breaking down the vulnerability components, using the concepts of susceptibility or sensitivity, and coping capacity or adaptive capacity (IPCC, 2012, 2014; UNDRR, 2020). In ESPON-TITAN we have opted combining susceptibility and coping capacity under the vulnerability assessment.

The diagram (Figure 1.1) synthesises and organises the hierarchy and linkages between the abovementioned concepts, identifying the main components of the ESPON-TITAN rationale. For a broader and more comprehensive understanding of the diagram, additional complementary definitions are included in the glossary of this report.

Figure 1.1 ESPON-TITAN conceptual framework

1.2 ESPON-TITAN rationale

One of the main goals of ESPON-TITAN is to provide evidence about European territorial patterns of direct and indirect economic impacts of natural hazards, in a DRM, CCA, and spatial planning policies context. The project has contributed to the state-of-the-art, building on previous datasets and methodologies of economic impacts assessment, developing them forward and analysing territorial patterns across the ESPON territory, supported by relevant and representative case studies. In addition, good practices of DRM and CCA have been analysed at different territorial levels, in order to provide policy recommendations for better considering economic impacts of natural hazards into integrated place-based spatial development effectively articulating DRM and CCA.

Considering the conceptual framework presented in Figure 1.1, disaster risk reduction through territorial development could only be addressed by decreasing exposure and vulnerability (i.e. reducing susceptibility and increasing coping capacity) or in terms of the climate change vulnerability rationale to reduce climate change vulnerability by decreasing sensitivity and increasing adaptation capacity. Under this scope, a broader understanding of the territorial vulnerability, considering both economic and non-economic factors as key determinants of disaster risk and potential future impacts and losses, is crucial. In these terms, in addition to territorial distribution of natural hazards and related economic direct and indirect impacts, ESPON-TITAN also analyzed patterns of territorial vulnerability.

ESPON-TITAN rationale is organized in sequential coordinated activities (Figure 1.2) allowing the precise articulation among its findings, developing a comprehensive knowledge base.

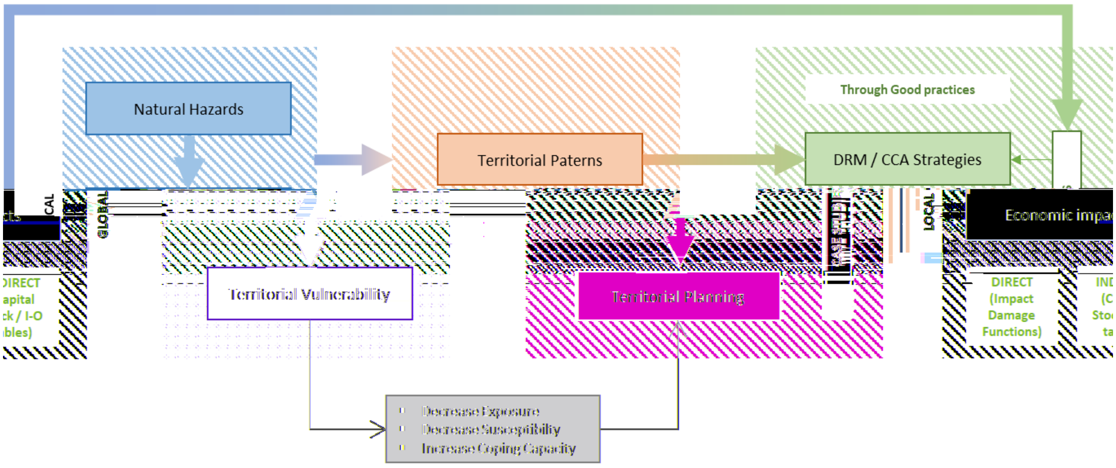


Figure 1.2 ESPON-TITAN methodological framework, taskflow

As a starting point, ESPON-TITAN analysed to what extent European regions have been exposed to specific **natural hazards** (river floods, droughts, windstorms, earthquakes, and landslides based on modelling results including empirical meteorological data, information about past events and other relevant susceptibility data). Existing information for these natural hazards has been processed and analysed to generate comparable datasets of the distribution of single, aggregated and combined hazard maps.

Trends and territorial patterns of related economic impacts affecting different types of territories were quantified along the European territory at NUTS3, providing an overview of economic impacts per natural hazard and per affected area and sector. The outputs offer a wide perspective of the distribution of those economic losses in terms of monetary value and selected related economic indicators as, for example, Gross Domestic Product (GDP) or Gross Value Added (GVA).

Considering the different types of natural hazards at NUTS3, a dual and complimentary methodology at global and local level has been developed to analyse both their **direct and indirect economic impact.** The global methodology has been used to estimate the direct and indirect economic impact of the four selected natural hazards across Europe, where related economic losses were disaggregated among several capital stocks (inferred from land-use) and among the affected regions, to feed an I/O model for assessing indirect sectoral and regional impacts. In turn, the local methodology was applied at a more detailed scale, which allowed for more finetuned and bottom-up information about the direct and indirect economic damages. Whereas the global methodology develops a generic damage assessment framework, based on cost estimates from available databases, the impacts in local methodology are assessed based on the outcome of chosen case studies.

Although economic impact patterns constitute the backbone of the ESPON-TITAN approach, the **territorial vulnerability** of European regions were assessed in order to provide a wider picture for DRM and CCA. Impacts are not simply the results of hazardous events, but the product of the social, political and economic context in which they occur. This argument is fundamental in the context of ESPON-TITAN, and actually it is the main reason why including a complementary territorial vulnerability analysis, considering other risk determinant factors in addition to hazards distribution and economic impacts.

The results of the territorial vulnerability analysis were compared with the distribution of past economic impacts and natural hazards at NUTS3 level in order to assess the spatial relations between them and their explanatory capacity. This result contributed to identify good practices and policy recommendations at several levels.

Eight **case studies** distributed heterogeneously in Europe, and presenting different characteristics in terms of hazards, economic impacts, governance, among others, are at the core of the ESPON-TITAN. They are designated to test and validate the methodologies and the results derived from the economic impacts analysis and to inform planning on DRM and CCA, as well as policy recommendations at EU, regional and case study scales. Besides, two, out of those eight, count on a tailored economic impact analysis, providing a higher level of detail allowing more precise and focused policy recommendations.

Effective approaches for mapping economic impacts of natural hazards are necessary to support planning processes at multiple scales. Supported by the previous findings, ESPON-TITAN provides an overview of the **policy framework and good practices related to DRM and CCA strategies**, based not only on the desk-based analysis of instruments identified at varied policy levels, but also upon the outcomes provided by the case studies analysis.

As a result of the analysis performed at ESPON-TITAN, **policy messages and recommendations** on how to better assess the potential economic impacts of natural hazards and adapt to related risks and a changing climate are presented, enabling decision makers to better face those challenges.

1.3 ESPON-TITAN messages

ESPON-TITAN brings answers to some research questions related, on the one hand, the territorial patterns of hazards and their economic impacts in Europe, considering as well how vulnerable different regions are to them; and on the other, how existing policy instruments regarding disaster risk management and its integration as a place-based strategy into spatial planning, contribute to minimize the effects and consequences of disasters.

The findings that respond to those concerns support the proposition of ESPON-TITAN concluding messages and policy recommendations.

The main results are covered through five key messages, and as so is this report organized. Although messages are indissociable, each of the following chapters covers one main driver, extending as well on how it is integrated and at which level it affects other issues tackled within the research, in a circular way (Figure 1.3).

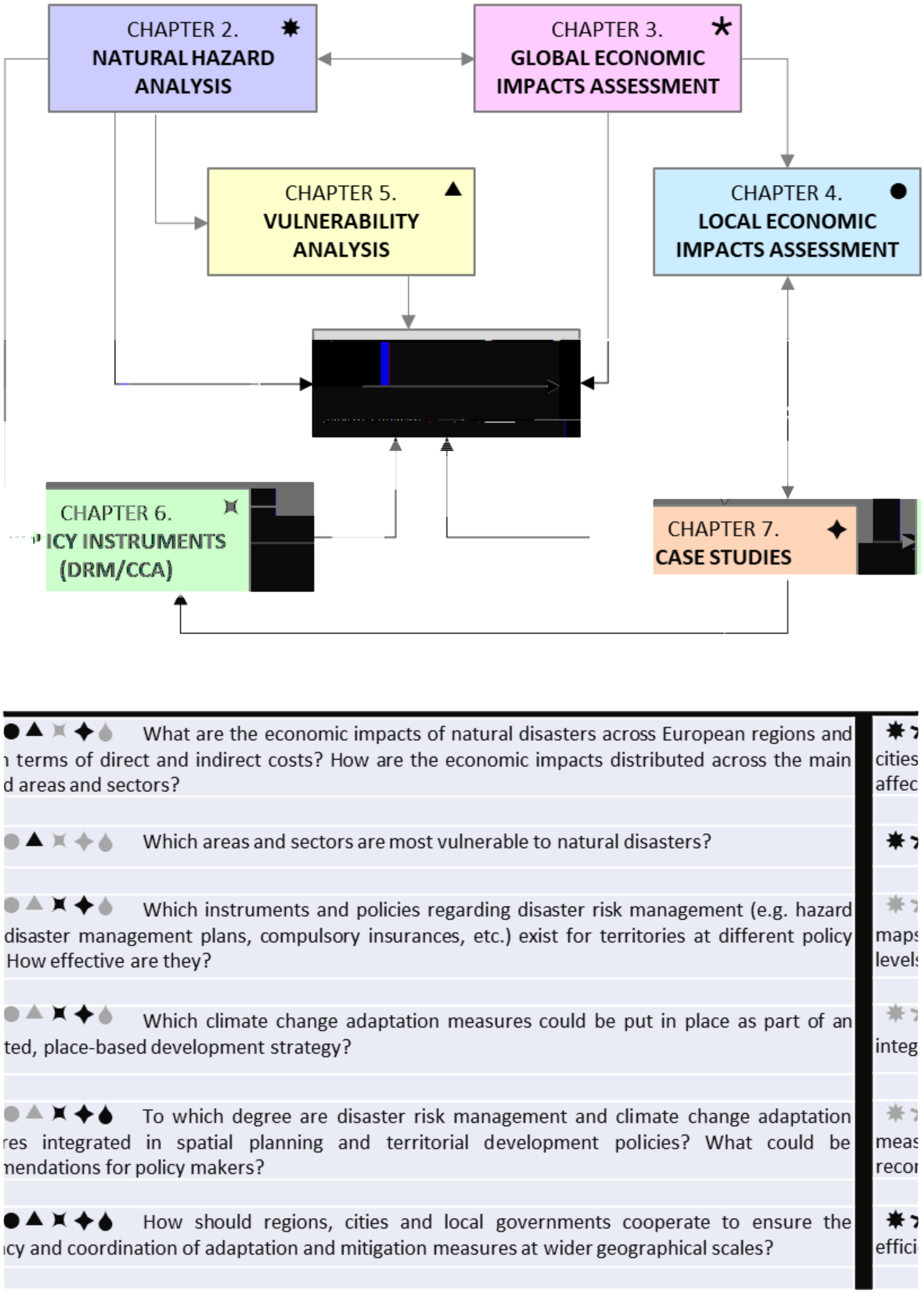


Figure 1.3 How ESPON-TITAN messages are related and respond to the research questions

The chapters in this report are organized in a way that each key topic is presented in a specific section, with the associated findings and related policies, in an integrated way, i.e. indicating the input-output interrelation and dependencies between different tasks of ESPON-TITAN.

2 Natural Hazards Patterns in Europe

From a European perspective, river floods and windstorms are the most relevant natural hazards of the five hazards analysed in ESPON-TITAN.

The analysis of the distribution and the identification of territorial patterns of natural hazards across the ESPON space forms the basis of the ESPON-TITAN project. ESPON-TITAN reviewed available data

and earthquakes were deemed the most crucial hazards at European scale. Landslides were included at a later stage to this project, as they are a very widespread natural hazard in Europe, but affect very localised areas. The data were processed, analysed, grouped and displayed at NUTS3 level (as far as possible) for each individual hazard. Further assessments are the combined occurrence of selected hazards (Annex 1) and an aggregated hazard map weighting the relative importance of individual hazards.

2.1 Individual and joined analysis of natural hazard distributions

From a European perspective, river floods and windstorms are the most relevant natural hazards of the five hazards analysed in ESPON-TITAN. Seismic (earthquakes) and landslide hazards are very important hazards on regional and local levels, and droughts can affect large areas over longer time periods. However, the total damage caused by droughts and earthquakes in the ESPON space is considerably smaller than the damages caused by river floods and windstorms whereas the recorded total damages caused by landslides are only a fraction of the damages caused by all other natural hazards (see Annex 1 for a full description of the methodology of the hazards´ maps).

2.1.1 Aggregated hazard map

For the aggregated hazard map, the relative weight of each chosen natural hazard was calculated by using the cumulative damage costs from Emergency Events Database (EM-DAT) for the period for each ESPON-TITAN hazard (EM-DAT, 2020). The database contains essential core data compiled from various sources on the occurrence and effects of disasters with significant impact[7]. The total estimated damage values include all damages and economic losses directly or indirectly related to the disaster. Table 2.1 shows the cumulative total damage costs and the calculated relative weights of ESPON-TITAN hazards.

Table 2.1 Cumulative damage costs and relative weights of the five ESPON-TITAN hazards

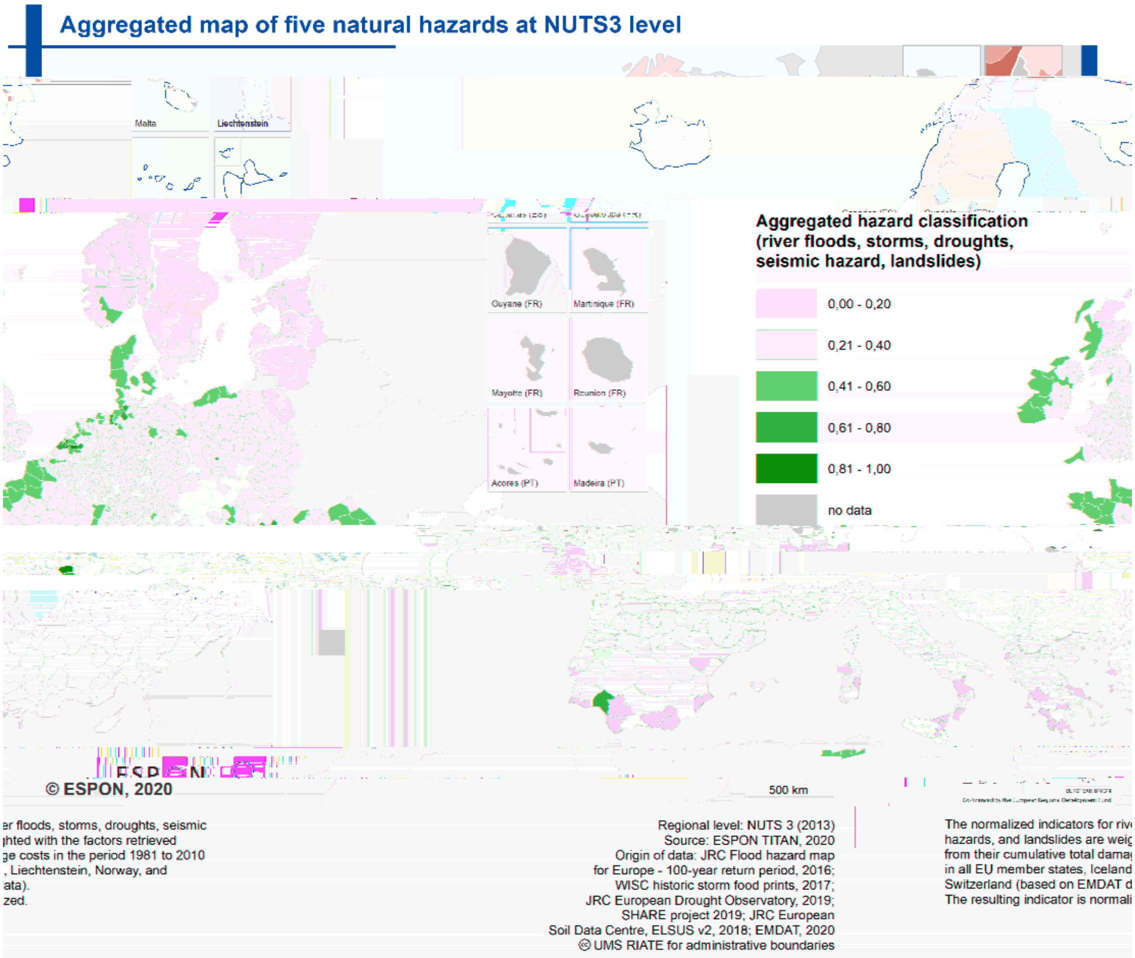
Winter storm/ Extra-tropical storm[8]	73.010.360	38,8
River flood	69.855.236	37,1
Drought	23.928.282	12,7
Earthquake	21.154.277	11,2
Landslide	262.597	0,1

[7] According to EM-DAT (EM-DAT, 2020) each disaster included in the database must have fulfilled one of four following criteria: hundred or more people reported affected, ten or more people reported killed, declaration of a state of emergency or call for international assistance.

[8] The cumulative total costs of windstorms include storm damages and damages caused by associated storm surges (personal communication with EM-DAT 8/12/2020, personal communication with Munich RE 29/12/2020). EM-DAT is working with specific criteria to decide if a hazard is taken up or not, but especially the way costs are gathered the costs are not calculated, but based on gathered info (often underestimated); indirect costs are not considered.

It is almost impossible to exclusively judge hazards without considering the exposure and vulnerability of the system at stake (Olfert et al. 2006). To minimize the influence of exposure and vulnerability of individual areas on the European-wide weighting, the chosen method is based on cumulative damages caused by the five hazards for the entire ESPON space. The cumulative damage costs provide the relative importance at European level instead of national or local level.

The calculated relative weights for each of the chosen five ESPON-TITAN hazards were multiplied with normalized hazard indicator values (0-1). The summed-up and normalized resulting values are shown at NUTS3 on an aggregated hazard map (Map 2.1).



Map 2.1 Aggregated hazard map

The interpretation of this map considers the weighting of the aggregated hazards based on the economic damage caused during the period 1981-2010[9]. In this period, river floods and windstorms have contributed to nearly 76% of all damages, followed by droughts and earthquakes, responsible only for almost 24% of the damages. According to EM-DAT data, economic damages caused by landslides are next to neglectable, from a European perspective. The high intensity of the windstorm hazard combined with high weight of windstorms when compared to other hazards is represented in the higher hazard classes, mostly on areas closer to exposed coasts. Many of these coastal zones, partly low-lying areas, also experience river floods Other areas with higher aggregated hazard values are based on the combination of other important hazards,

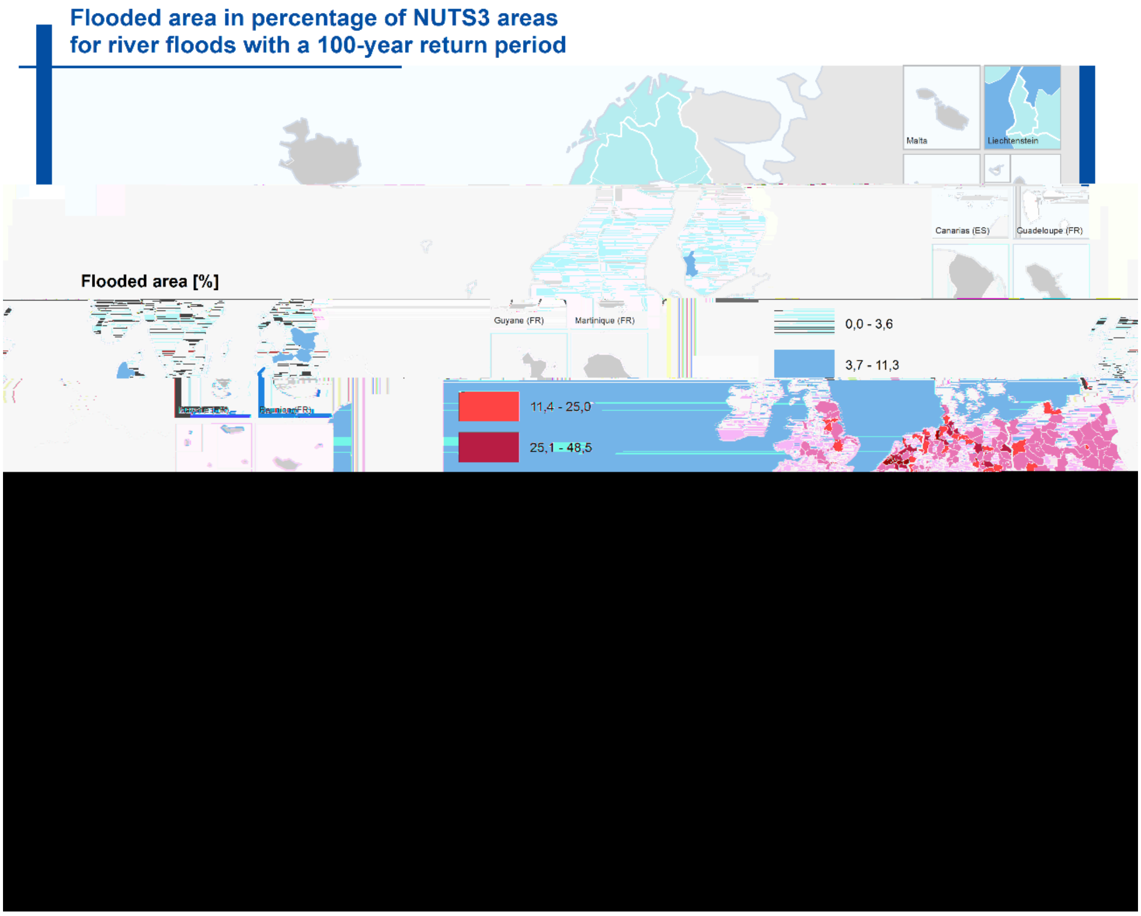
[9] Up the end of 2020 the period 1981-2010 was the standard reference period, as defined by the World Meteorological Organization (WMO). By referring to this period, the ESPON TITAN results are comparable to a wide range of currently available climatic data.

such as floods and droughts (e.g. Eastern Romania). It must be considered that the aggregated hazard map does not respect any flood protection measures, therefore some areas have a high aggregated hazard potential, meanwhile the effective risk is neglected. Also, the drought potential is displayed on NUTS0, which partially leads to strong contrasts at national borders. It must be further considered that the weighting of the aggregation is based only on economic damages, and not human fatalities or damages that cannot be expressed in monetary values. The general picture would certainly be very different if fatalities would be used for the weighting instead of economic damages.

2.1.2 River floods

River floods have an impact on territories along major rivers, and estuaries are especially flood prone. Map 2.2 displays this hazard pattern, as the percentage of flooded area in case of a flood with a 100-year return period for NUTS3 areas in major catchment areas across Europe. Many of the NUTS3 areas highly affected by river floods belong also to the hazard prone areas on the aggregated hazard map (Map 2.1).

An observation derived from this map is that several highly industrialized areas count with a high percentage of flooded area, so that special attention should be placed on this hazard to avoid risk chains, such as interruptions in the production and trade (flooded or destroyed transport routes), as well as Natural-technical hazards (NATECHS), i.e. flood events leading to environmental impacts (flood waters washing out contaminants of industrial areas and brownfields) (see also Policy Recommendations A-4 and A-5 in Chapter 8).

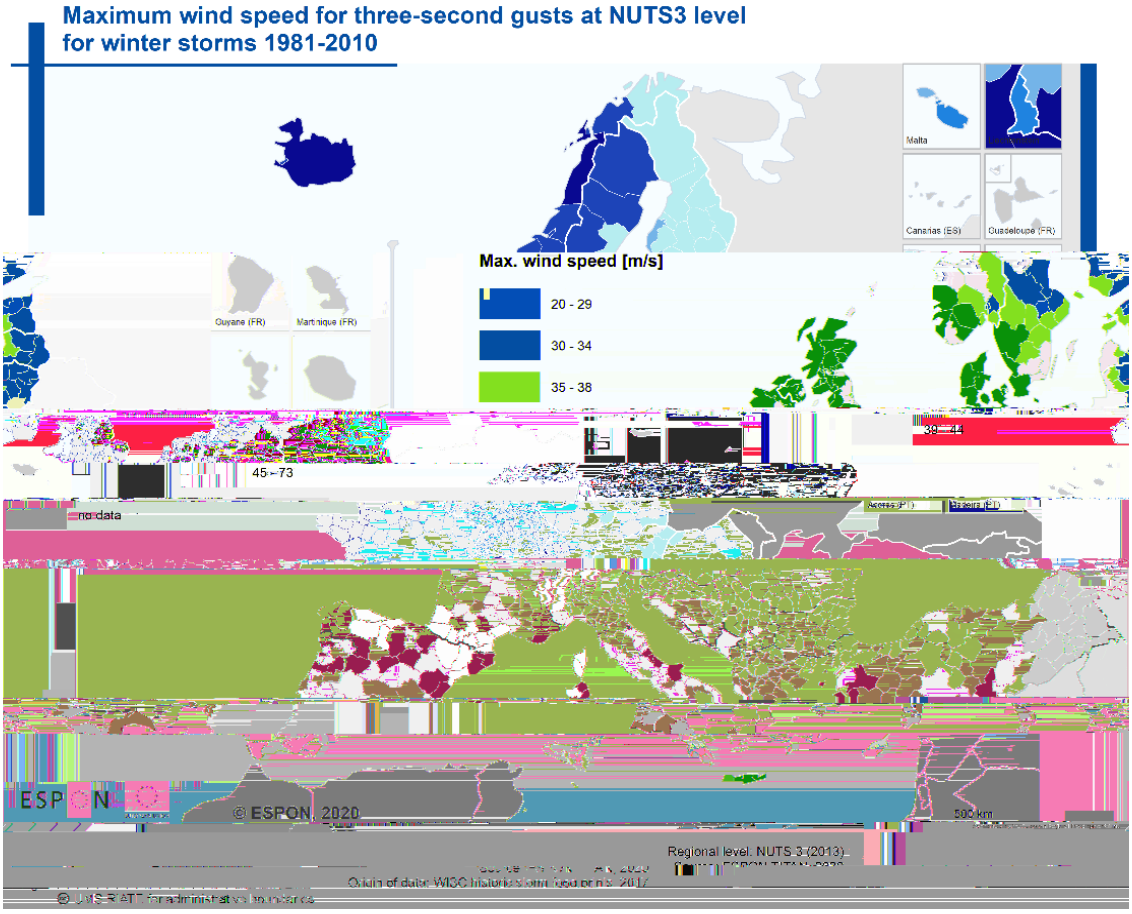


Map 2.2 Flood hazard map (flooded area in percentage of NUTS3 areas for river floods with a 100-year return period)

2.1.3 Storms

Areas most affected by windstorms are coastal regions of the North Sea and exposed coastal areas of the Baltic Sea. Further affected are some specific coastal areas of the Mediterranean region by local windstorm patterns, as well the mountain regions of the Pyrenees and the Alps. The storm hazard map (Map 2.3) shows maximum 3-second gust speeds (m/s) over a 72-hour time period for winter storms in the years 1981-2010 at NUTS3. ESPON-TITAN limits its analysis to winter storms and extra-tropical storms, because in the ESPON space, they account for the largest part (<95%) of damage costs caused by windstorms (EM DAT, 2020).

As a general observation, this implies that particularly coastal areas must take this hazard into account in planning systems, along with rising sea levels caused by climate change even more so. A combined river and storm surge analysis for coastal areas in the ESPON space could provide additional insight (see Annex 6 for further information).



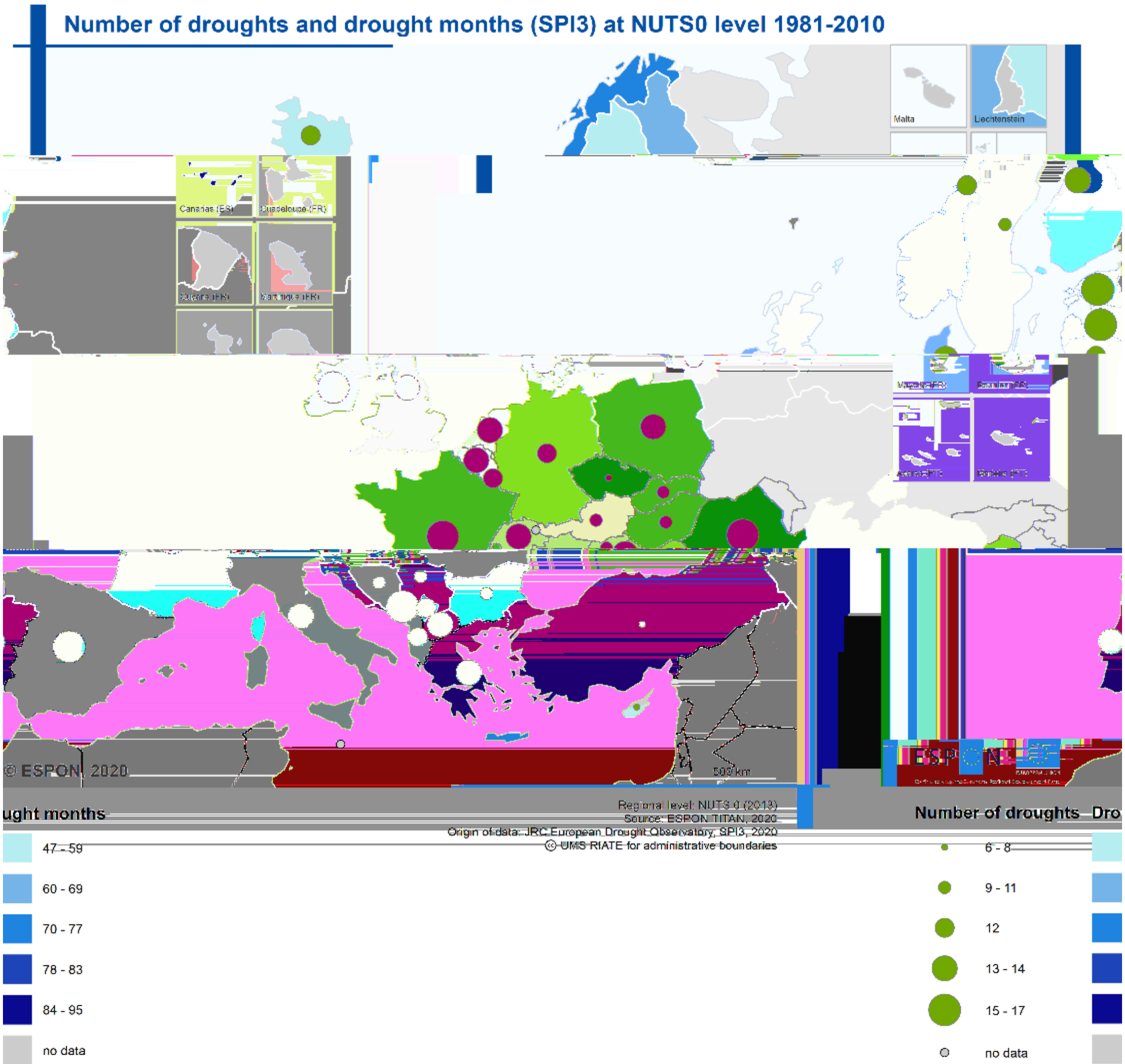
Map 2.3 Storm hazard map (maximum wind speed for three-second gust at NUTS3 for winter storms, 1981-2010)

2.1.4 Droughts

The drought hazard map (Map 2.4) shows the number of droughts and the number of months under drought conditions for each country (NUTS0). The hazard assessment utilizes the Standardized Precipitation Index for three-month periods (SPI3), which shows deviations from the average three-monthly cumulative precipitation (Spinoni et al., 2019). It is an indicator for short-term impacts such as reduced soil moisture or reduced flow in small creeks (i.e. mostly meteorological droughts).

Eastern Europe and Western Europe experience a larger number of months with meteorological drought conditions than other areas. However, droughts are difficult to map, because droughts are always relative ted than other hazards (e.g. river floods). Drought patterns for other drought types (e.g. agricultural or hydrological droughts) and other geographic reference areas might in fact be quite different to the results presented in the drought hazard map (Map 2.4).

Besides, it must be considered that the effects of droughts also largely depend on topography, landcover and land-use.



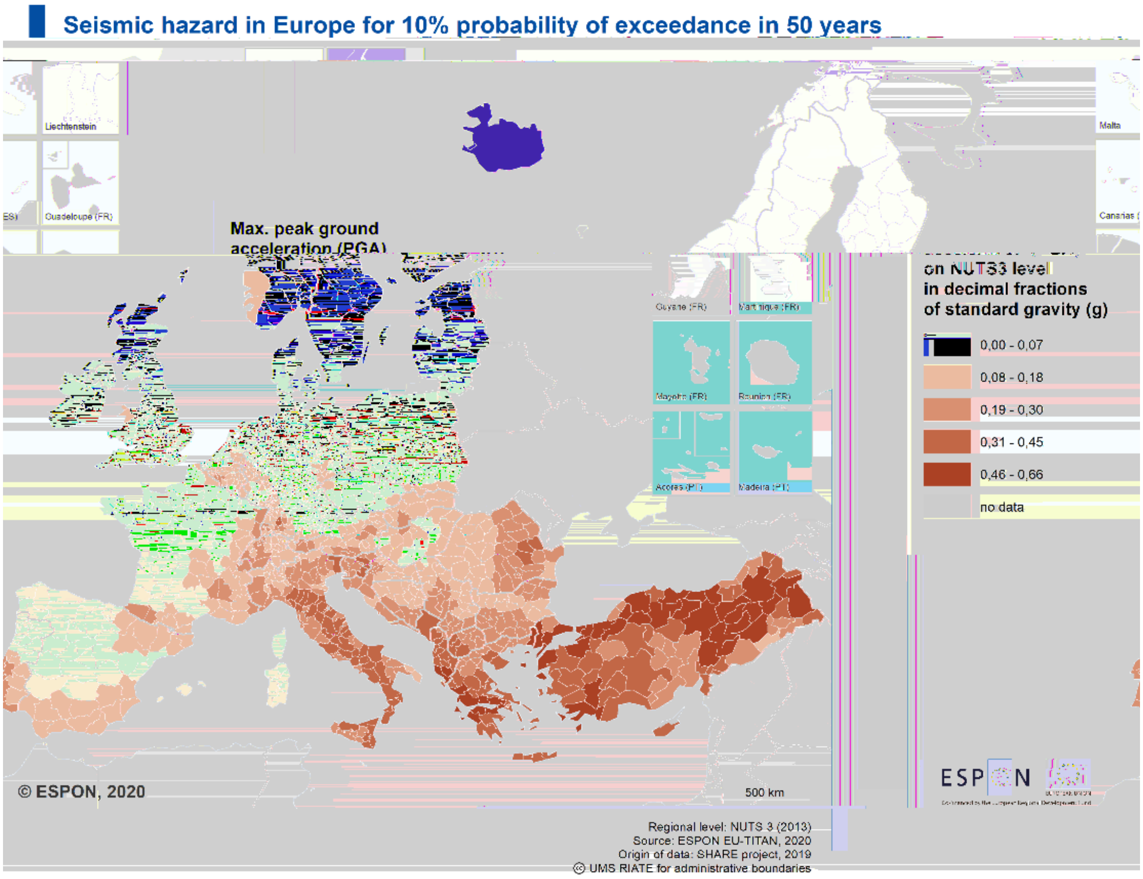
Map 2.4 Drought hazard map (number of droughts and drought months at NUTS0 for the period 1981-2010)

2.1.5 Earthquakes

Seismic hazards affect most strongly Northern and Central Turkey, the Balkan, the Eastern Mediterranean and the Black Sea coasts, followed by a lesser hazard degree in the Western Mediterranean region, the Alps and the Carpathian mountain ranges.

Map 2.5) displays the territorially distributed intensity of ground-shaking with a certain probability of exceedance rather than the occurrence of earthquakes at specific locations.

The seismic hazard must be analysed locally, and ideally the location of active faults are respected in local land-use plans and building codes. It must be further considered that seismic events can cause tsunamis, and information about this hazard potential should be offered in potentially affected areas.



Map 2.5 Earthquake hazard map (maximal peak ground acceleration in decimal fractions of standard gravity at NUTS3)

2.1.6 Landslides

Landslide is an additional hazard analysed in ESPON-TITAN, included at European level given the availability of data, although the analysis is more coherent and relevant when done at a regional and local ss movements (here represented by the EM-DAT disaster subtypes landslide, mudslide, and rockfall). The landslide susceptibility is mostly driven by slope angle, elevation, lithology, and land cover. This results in a higher susceptibility in all mountainous regions in Europe. The correspondent map and analysis are presented in Annex 1.

2.2 Policy relevance of the hazard distribution analysis

The hazard maps of ESPON-TITAN suggest that there is a need for a differentiated approach. River floods and windstorms (and to a certain extent droughts) are hazards that can be addressed by dedicated European-wide approaches, whereas earthquakes and landslides can be addressed by supporting regions and the local level in using research and cooperation projects more strategically for DRM and CCA. Irrespective of the type of hazard, the EU can play a crucial role in supporting preventive risk management for hazard with cross-national impacts and in supporting areas in responsive risk management after harmful hazard events. These reflections are both considered within the ESPON-TITAN policy recommendations D-1 and A-6 (Annex 6).

3 Economic Impacts of Natural Hazards in Europe

Historical data of natural hazard´s severity and occurrence, combined with a modelling of the economic impacts of the hazards through multi-regional input-output (I/O) tables revealed that indirect economic impacts (inferred from supply chain effects) can be almost as large as direct impacts on productive capacities of the regional economies. While the assessed impacts consider production losses and supply chains impacts, they do not account for potential interruptions of critical infrastructure (e.g.: airports, bridges or the Trans-European Transport Network). Consequently, the real potential indirect losses could be even higher than assessed.

One of the aims of the ESPON-TITAN project is the analysis of the direct and indirect economic impact of natural hazards (i.e. river floods, earthquakes, droughts and windstorms) in Europe at global level (applicable across all European countries using available data). To estimate the direct and indirect economic impact of disasters across Europe[10] with the global methodology, related disaster economic losses were disaggregated among several capital stocks and among the affected regions to feed into an I/O model for assessing indirect sectoral and regional impacts on a yearly basis between 1995 and 2017. Headline figures of the analysis are largely in line with the findings of some other related studies, in particular with results of the latest PESETA IV report (Szewczyk et al., 2020). While our current evaluation considers economic impacts in terms of GVA drop, the PESETA report accounted for the impacts in terms of total welfare losses (foreseen % loss of GDP), and for a different time period in assessing the impacts. The relative volume and severity of disaster impacts are balanced among each other.

Although the loss of human life and its monetisation is outside the scope of this project, it is important to note that the reported natural hazards have certainly caused fatalities, aside from the economic impacts; especially for earthquakes and floods, the number of fatalities per event can be considerable.

3.1 Analysis of the economic impact of disasters: global approach

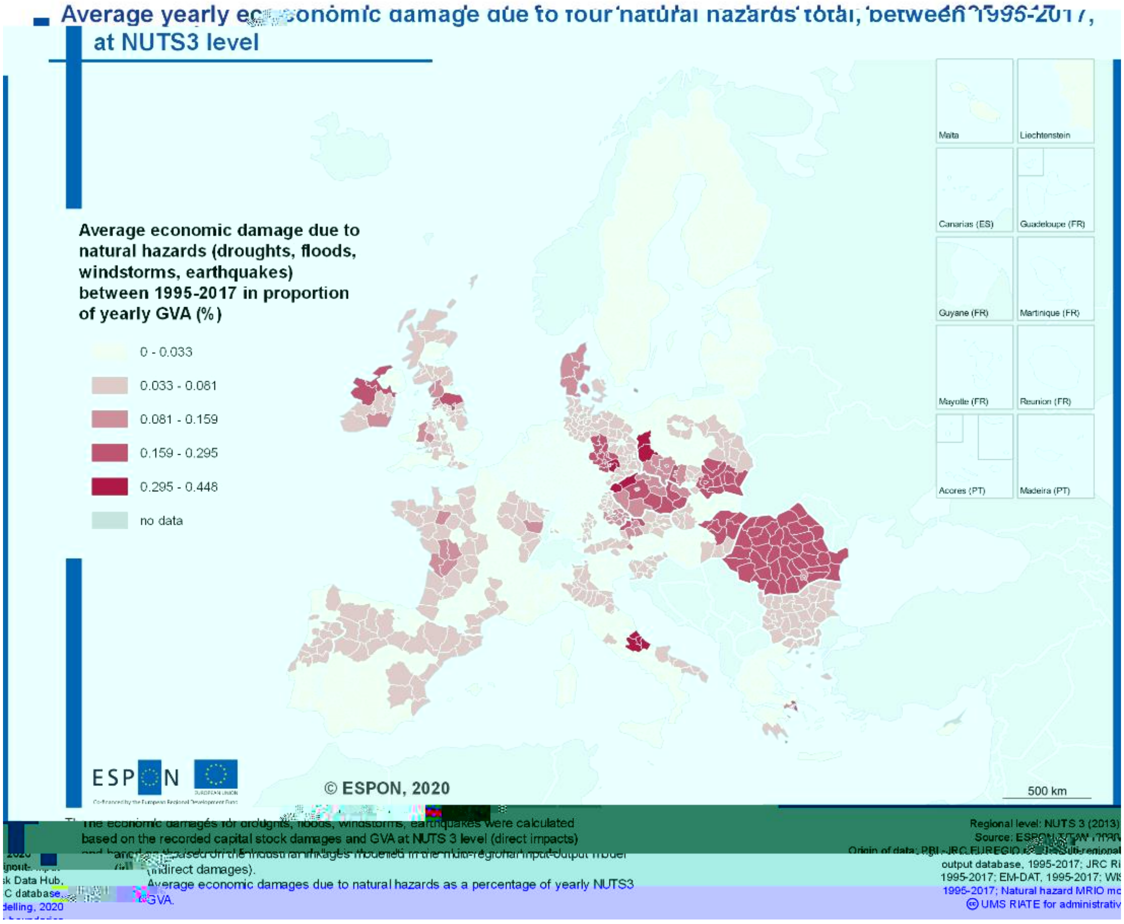
The spatial distribution of the economic impacts indicates that **Central and Eastern European** and the investigated **Southern and Eastern European** countries tend to be relatively more affected by these types of natural hazards, in economic terms than most other parts of Europe. However, it is also key to highlight that some of the hazards (e.g.: windstorms) do not follow this pattern, rather are related to coastal or mountainous areas. This is partly due to the GVA of these regions being relatively lower (compared to, e.g.: Northern European countries), thus a certain event may cause a relatively larger damage, compared to their local GVA. This further implies that these **countries are highly recommended to derivate their own measures to mitigate the effects of these events** (cross-border initiatives cannot be concluded with the used datasets).

Besides Central, Eastern and Southern European countries, results of the economic impact assessment indicate that certain NUTS3 areas of the UK and Ireland, Denmark, France and Spain are also highly affected by one or more natural hazard event types across the period 1995-2017.

The Map 3.1 shows yearly average economic damage due to the four natural hazard types, aggregated (measured in terms of the ratio of economic output drop compared to GVA, in percentage terms) for the

[10] It is worth noting that not all ESPON regions could be covered in the economic analysis due to data availability. The multi-regional I/O dataset, which has been a core part of the economic impact analysis, covers 250 European NUTS2 regions. Croatia was not included in the I/O dataset. Romania and Bulgaria were included as country totals only - thus, indirect impacts for these countries were first calculated at the country-level, and final results have been disaggregated to NUTS3 regions. ESPON Partner States (Iceland, Liechtenstein, Norway and Switzerland) were not included in the economic analysis (see section 8.2. for related policy recommendation).

period 1995-2017, at the NUTS3 level for the whole ESPON area (with available data). It is important to stress that while displaying average yearly impacts over such a long time period in one map does provide important insights with regards to territorial patterns of economic damages, it may be the case that certain regions with relatively rare but large impacts smoothly diminish across the time period and thus do not show as heavily affected on a map presenting averages. Therefore, more insightful observations can be taken by looking at data in specific years when comparing the impacts across regions and across event types (e.g.: severe impacts of Lothar windstorm in certain regions of France in 1999). Also, while the global approach of economic impact assessment aimed at being as comprehensive as possible in terms of results and coverage, certain relevant events may have been excluded from the analysis, in the case the public database from which input data was collected did not include data on the related total damage cost. Lack of data (or partial availability) is, and has always been, one of the main challenges when producing models and developing methodologies based on publicly available European databases.



Map 3.1 Economic damage due to the four natural hazard types, yearly average 1995-2017, at NUTS3 level

This section discusses headline economic impacts of the global methodology applied. Within total economic impacts, direct impacts (induced by direct damage to capital stock) and indirect impacts (induced by disruption of economic activities in other, linked regions) have been differentiated, as well as impacts by each of the analysed types of natural hazards: flood, drought, windstorms and earthquakes.

Both the multi-regional I/O tables and the dataset on regional capital stock used for the analysis included data at NUTS2 level, which means that the economic impact of disasters, in the first round, was derived at the NUTS2 and then disaggregated to NUTS3 in order to reach the final distribution. Disaggregation of the impact results was done in line with Eurostat data on yearly data on GVA at basic prices by NUTS3 and economic sectors (Eurostat, 2020). As Eurostat dataset covered all NUTS2 (and related NUTS3) regions and all the economic sectors of interest, results of a specific NUTS2 and industry could be disaggregated to the corresponding NUTS3 regions and industries, using proxy shares for distribution (the same shares as GVA is distributed across these NUTS3 regions in NUTS2 totals).

Figure 3.1 presents the total direct and indirect impacts of natural hazards, captured as a change in gross economic output, in the analysed NUTS3 regions as a whole, for the years 1995-2017. The presented

output, directly or indirectly induced by natural hazards. While the yearly economic damages collected for the relevant regions and sectors were aimed at being as full as possible in terms of inclusion of natural hazards, due to rational limitations of research, there have necessarily been cases of natural hazards not included in the impact analysis (e.g. the flood event related to the 2010 windstorm Xynthia in Charente-

case study). This may explain the relatively large volatility of yearly total impact estimates in the chart.

Overall, total direct economic impacts over the period 1995-2017 amount to EUR 43,8 billion in sum, while total indirect economic impacts amount to EUR 32,6 billion, aggregated, over the same time period.

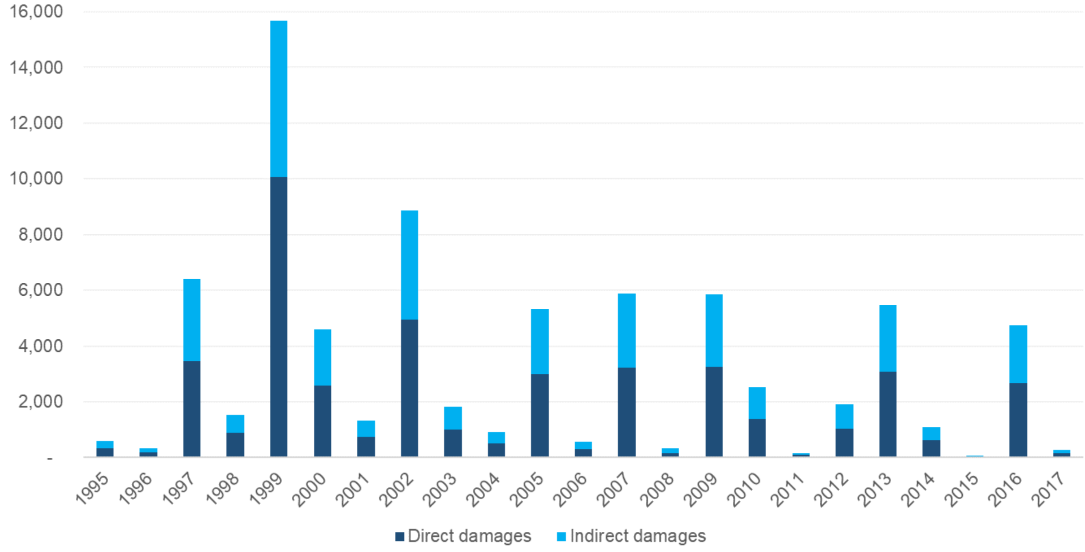


Figure 3.1 Total direct and indirect economic damages induced by disasters in NUTS3 (1995-2017), drop in gross economic output, current EUR million

Nevertheless, an important insight from total damage data, applicable for all analysed years, is that indirect economic impacts, induced in specific regions by a disruption of economic activities in other, linked regions tend to be almost as large as direct impacts. Direct impacts are those damages resulting from a natural hazard hitting a region directly (geographically happening there), while indirect impacts are derived through the use of I/O tables, making use of the observable linkages of economic sectors across regions and countries. The ratio of indirect impacts to direct impacts falls between 60% and 90% in all of the assessed years.

Additional observations can be made through analysing the distribution of economic impacts across the four event types in the investigated years. Regarding the monetary losses attributed to the specific types of natural hazard events, according to the following chart, in an aggregated view across Europe, flood and windstorm events have had the largest negative impact on economic output in almost all analysed years. Quite reasonably, and well-illustrated by the year 2009, heavy earthquake events, despite being rare, tend to result in significant economic losses compared to other event types. Please note that the Figure 3.2 shows only those natural hazards events where direct capital stock damages data was available.

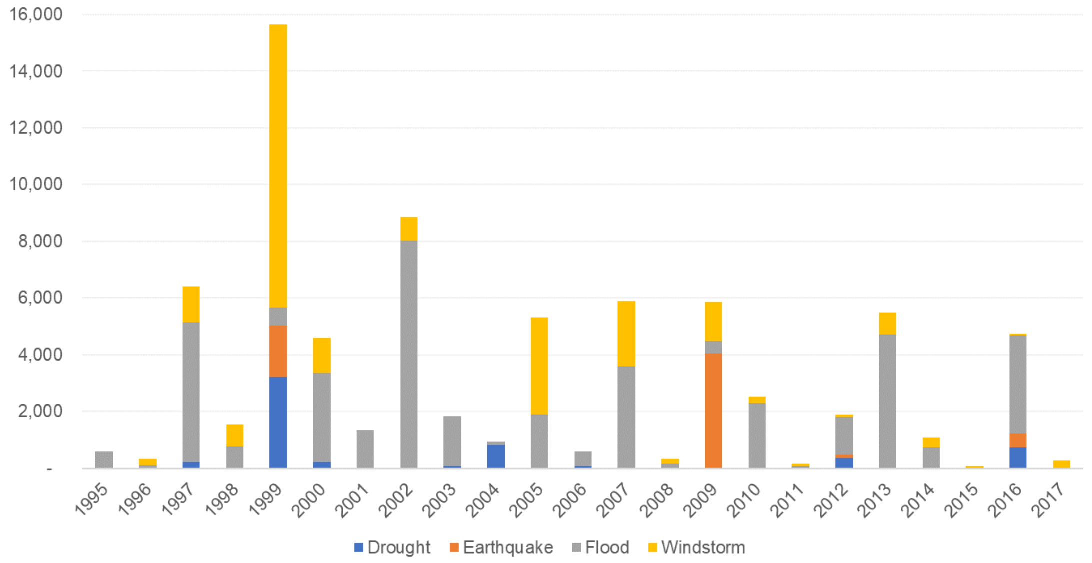


Figure 3.2 Total economic damages induced by four types of natural hazards in NUTS3 (1995-2017), drop in gross economic output, current EUR million

With regards to the impact of specific event types in the NUTS3 regions of interest, the results support the assumption that some NUTS3 regions across Europe tend to be more vulnerable to certain types of natural hazards, while other regions are less impacted. However, results of indirect impacts also support the assumption that supply chains, represented by I/O linkages, are highly important in distributing the economic

3.2 Potential economic impact in relation to hazards

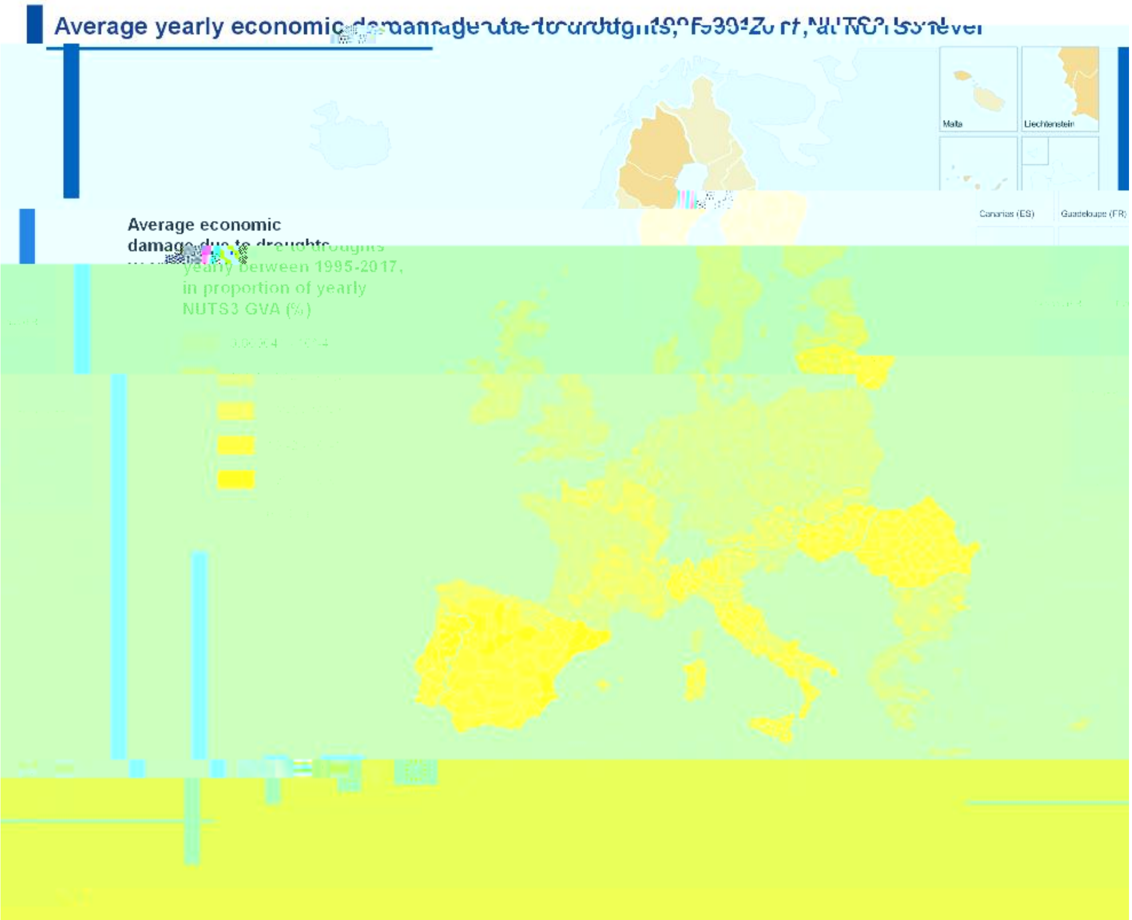
For two of the investigated hazard types (droughts and windstorms), data availability of past disasters allows to be a proxy indicator for a comparison of the historical severity of hazards and the average yearly economic impacts of disasters across the same period (1995- storical severity and the average economic impact show considerable spatial correlation in case of both droughts and windstorms. **A key message based of these findings is that historical data of hazards' severity and occurrence, combined with a modelling of the economic impacts of the disasters through multi-regional I/O tables can be a powerful tool in estimating future potential economic damages caused by hazard events in specific economic sectors at the NUTS3 level**.

Based on the Map 3.2 displaying droughts, it can be observed that drought hazard affects a large number of countries, but to varying effects - droughts also occur in several countries that might usually be seen as rather rainy (such as the Benelux countries or the Baltic states). However, the countries to the South-West of Europe tend to experience relatively more drought events than other countries.

[redacted]

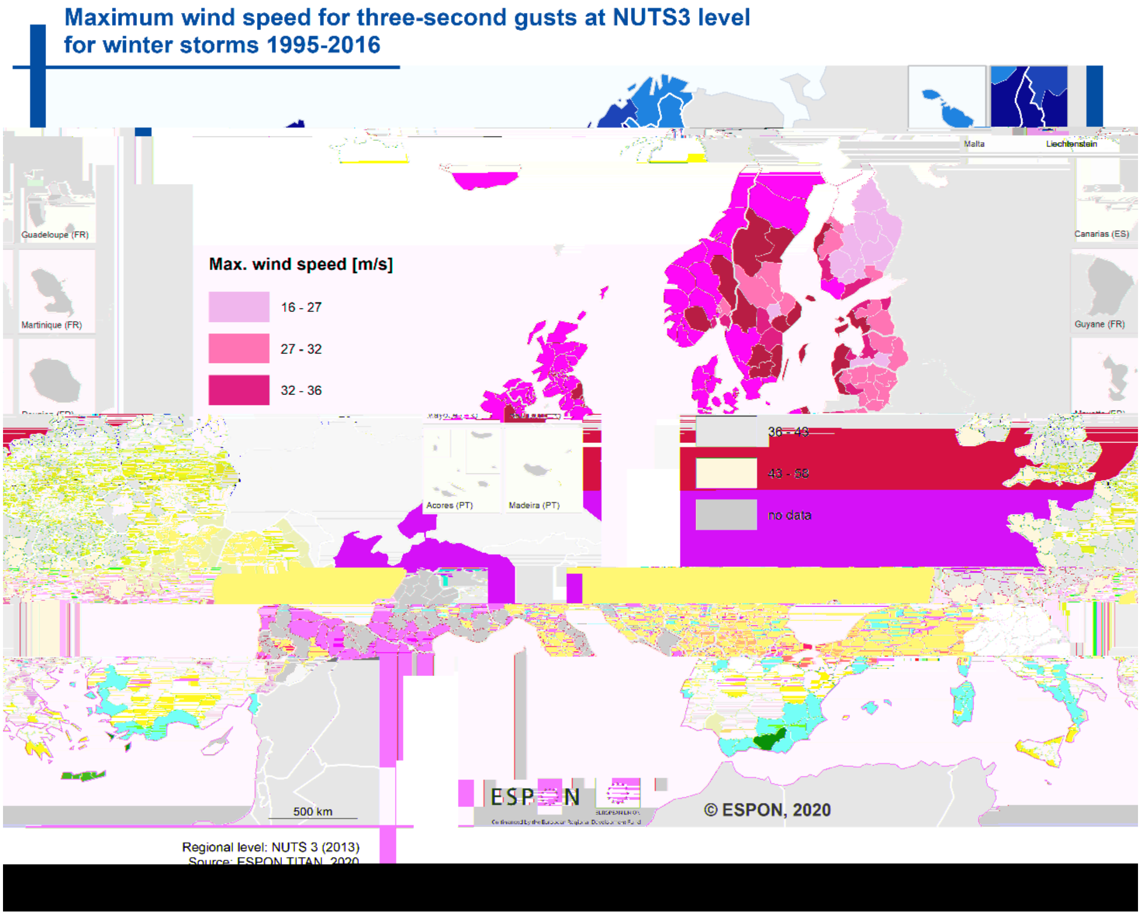
Map 3.2 Number of droughts and droughts months (SPI3) at NUTS0 level 1995-2017

This is also supported by the yearly average economic impacts for the same period, presented in Map 3.3. The countries hit most severely by droughts, in economic terms, are Mediterranean countries and certain parts of Central and Eastern Europe. While certain large countries, such as France and Germany tend to experience large number of droughts (and many drought months) across the period covered, in economic terms (damage as a percentage of regional GVA) they seem to be relatively less affected, compared to other, similarly drought-prone countries.



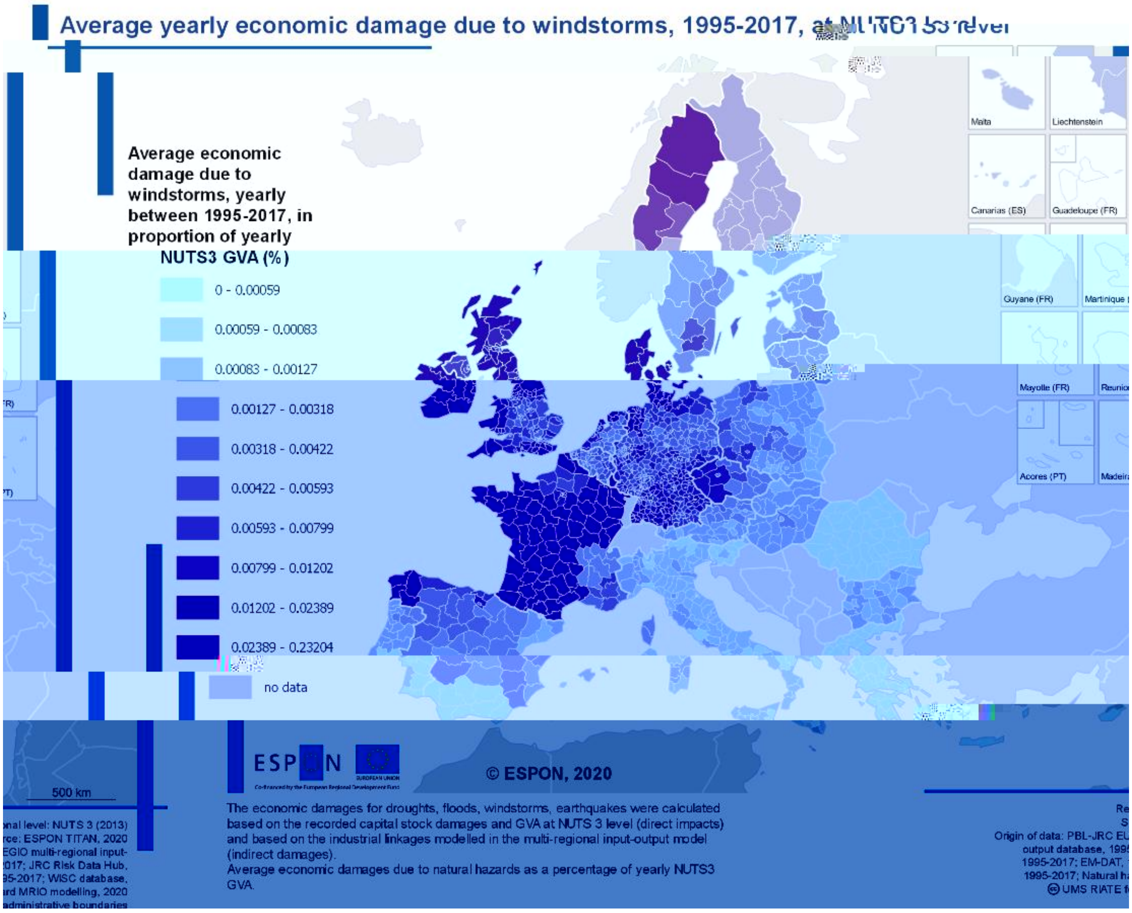
Map 3.3 Economic damage due to the droughts, yearly average 1995-2017, NUTS3 level

average economic impacts resulting from windstorm events. The storm hazard map (Map 3.4) shows that between 1995 and 2016, the areas most affected by windstorms are all Nordic, Western Europe and Mediterranean countries with coastal regions and most coastal areas of the Baltic Sea.



Map 3.4 Maximum wind speed for three-second gusts at NUTS3 level for winter storms 1995-2016

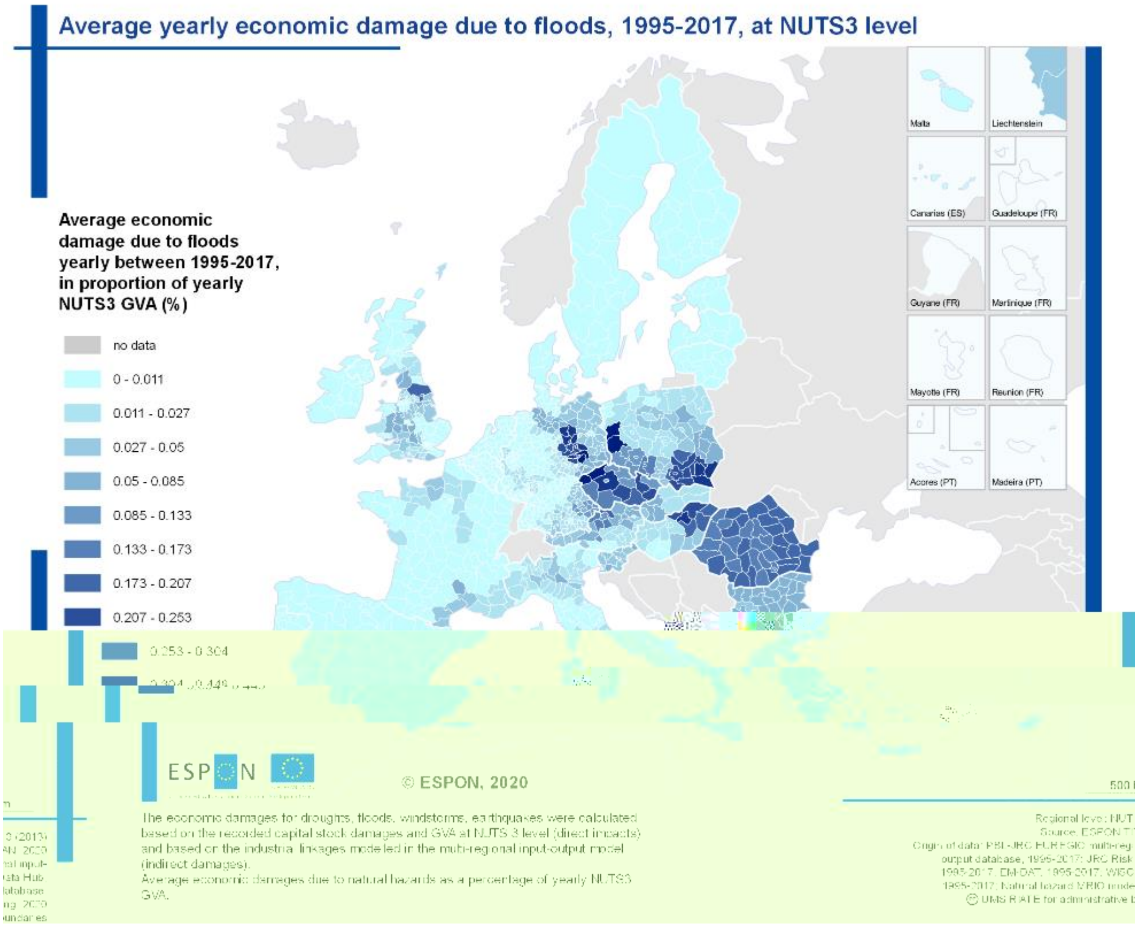
Map 3.5 displaying yearly average economic impacts of windstorm events supports these geographical patterns, in that Northern regions tend to be clearly more affected by these events, with the UK and Denmark being the most affected countries (measured in terms of the ratio of output drop compared to GVA), followed by several coastal regions of Spain and most not only the coastal regions of France, this last observation mainly driven by indirect impacts of events through supply chains in the affected regions.



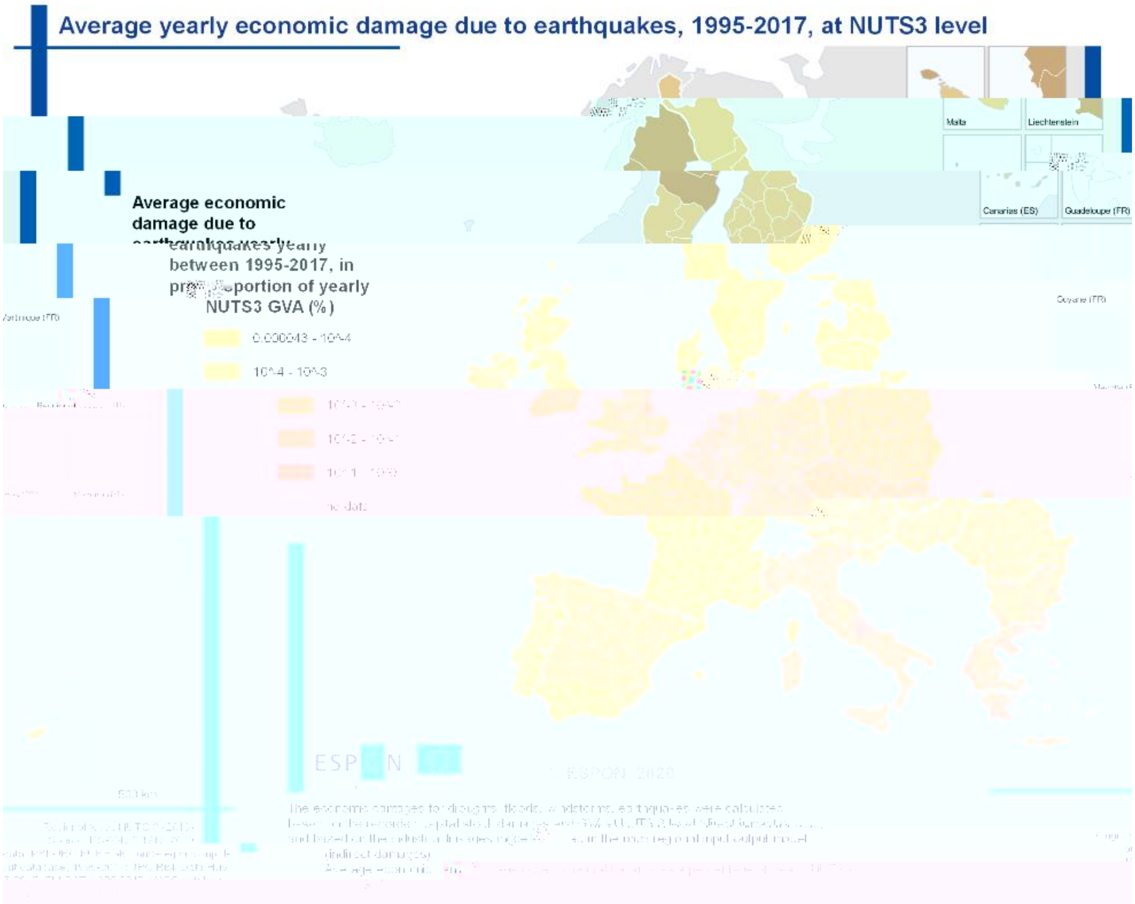
Map 3.5 Economic damage due to windstorms, yearly average 1995-2017, NUTS3 level

Map 3.6 and Map 3.6 display yearly average economic impacts resulting from flooding and earthquake events at NUTS3, between the period 1995-2017. The spatial patterns on these maps are correlated with verity across the ESPON area, as illustrated respectively on the Map 2.2 and Map 2.5 in the Chapter 2 of this report.

Countries hit relatively most severely by flood events are certain regions of Germany, and some Central and Eastern European countries (especially the Czech Republic, Poland and Hungary), in which countries and regions the impact of flood events, on average, may amount to 0,3-0,4% of yearly NUTS3 level GVA.



Map 3.6 Economic damage due to floods, yearly average 1995-2017, NUTS3 level



Map 3.7 Economic damage due to earthquakes, yearly average 1995-2017, NUTS3 level

3.3 Policy relevance of the global economic impact analysis

) call for an even stronger consideration of vulnerabilities / damage potentials / supply chains in the assessment and management of risk (rather than only looking on the hazard component); this could also mean to generate synergies between actions and would support a more preventive and spatially oriented disaster risk management.

The strong indirect economic impacts (in comparison to the direct impacts) rely on I/O models that consider production losses and supply chains impacts, but not potential interruptions of critical infrastructures (such as harbours, airports, bridges, TEN infrastructures, etc.). Consequently, the real potential indirect losses could be even higher than assessed; research on this aspect should be promoted/included into the I/O models.

Finally, not all ESPON regions could be covered in the economic analysis due to data availability. The multi-regional I/O dataset, which has been a core part of the economic impact analysis, covers 250 European NUTS2 regions; Croatia was not included in the I/O dataset, and Romania and Bulgaria were included as country totals only. Better data availability would further increase the depth of the analysis.

4 Downscaling through a Local Economic Impact Analysis

Whilst in the economic impact analysis performed at EU level the direct and indirect damages results to be quite similar, the local outcomes show that the direct damages increase to a relatively larger extent than indirect ones as a result of detailed bottom-up information.

In this section, the outcomes of the local analyses of the direct and indirect economic impacts are presented. Whereas the global methodology develops a generic damage assessment framework (based on cost estimates from available databases), the local methodology focuses on two specific test regions where impacts are assessed based on additional bottom up information (and as such more accurate cost data). This main message is based on the comparison between the outcomes of the global and local analyses (Annex 2). In the development of the Damage Distribution Matrices (DDM), the local and the global methodology differ, in the sense that the local one allows for a more in-depth understanding of the direct and indirect impacts as it uses refined data (on the basis of actual incurred events in the region), the capital stock information is adjusted to the NUTS3 region affected (when available) and adds qualitative research on economic impacts. In order to refine our data inputs at the local level and apply the local methodology, the following two test regions were selected:

Test region 1: Flooding of 2013 in Prague, Czech Republic

Test region 2: Windstorm Xynthia in 2010 in Charente-Maritime, France

4.1 Comparison between global and local analysis

Comparing the local outcomes with the global outcomes of the two test regions of Prague (Czech Republic) and Charente-Maritime (France) shows that the **local methodology results in higher reported direct damages for the same natural hazards than the global methodology** due to the inclusion of more detailed data on the damage costs.

Moreover, the local outcomes show that the **direct damages increase to a relatively larger extent than indirect damages** in the case of the flooding in Prague. For the test region of Charente-Maritime, this was not the case for the results of the I/O analysis as the direct and indirect damages increased proportionally. However, further analyses with the Spatial Computable General Equilibrium (SCGE) model shows a different trend as the magnitude of the indirect effects is relatively small.

4.1.1 Analysis of the Flooding of 2013, Prague

In 2013, Central Europe was affected by a severe flooding, mainly caused by the heavy rainfall in a number of already saturated river basins (Lorencová et al., 2016). Czech Republic was one of the most heavily affected countries

was EUR 623 million including 19.000 people affected and 15 fatalities. Prague has been the municipality

4.1.1.1 Comparison between the global and the local Damage Distribution Matrix

There is a large difference between the global DDM and the local DDM (Table 4.1) for the case study of Prague. The total of the global DDM totals EUR 63 million for the region of Prague whereas the total of the local DDM is EUR 245 million. This can be e

of sewers and underground pipes (interview data) which is not taken into account in our global methodology. Moreover, the house prices are almost three times higher in Prague than the rest of Czech Republic, which results in higher damage costs for residential buildings. This parameter is not included in the global methodology. The DDMs in Table 4.1 also show different percentages for the damages per capital stock. There is for instance a large difference between the share for residential buildings and their contents, which can be explained by the high house prices (among others). In the global DDM the share for commercial buildings and their content, together with the industry capital stock, is higher than the share in the local DDM. Both DDMs report high damages for infrastructure and transport and low damages for agricultural land. The comparison for the indirect impacts is discussed below (see results of the I/O analysis).

Table 4.1 Overview of the global and local DDM for the flooding in Prague in 2013

	Estimated damages in thousands of euros, 2013	Share of damages	Estimated damages in thousands of euros, 2013	Share of damages
Residential buildings and their contents	5.410	8%	86.986	36%
Commercial buildings and their contents	16.675	26%	31.112	13%
Industrial buildings and their contents	2.077	3%	Included in the number above	Included in the number above
Infrastructure and Transport	39.623	62%	84.501	35%
Arable land	19	0%	3.578	1%
Other	0	0%	38.560	16%
Total (2010 price levels)	63.806	100%	244.739	100%

Even though information applied in the local analyses is much more detailed than global data, there are some limitations to our local methodology and data inputs which should be considered when reading our results:

Especially for the local methodology, we depend heavily on the reporting (and the accessibility and readability) of local authorities and insurance associations. We have included many reports on costs and damages. However, as there are different ways of reporting for different institutes (i.e. the Czech Insurance Association and the government), there is a risk that certain costs are double counted for. To avoid these risks, we had informal exchange with authors of certain reports and an interview with the Prague Institute of Planning and Development;

The insured costs were only presented for the whole of Czech Republic. The numbers for Prague are based on our own calculations. We used, for instance, the share reported damages to residential buildings in Prague to assume the insured costs to residential buildings. We validated our assumptions by looking at historical events.

4.1.1.2 Results of the I/O analysis: Comparison between the local and global analysis for the direct and indirect economic impacts

The results of the economic impact assessment, when applying the local approach and using its finetuned data, clearly show an increase in the calculated economic damages (in terms of drop in economic output) compared to the global methodology for the 2013 flooding event in Prague. Direct damages increase to a relatively larger extent than indirect damages (Figure 4.1), resulting in a direct/indirect damages ratio of 1,3 for the NUTS2 CZ01 under the local methodology.

While the change is rather marginal at the total ESPON area NUTS3 level (2% increase in total damages for the year 2013), the finetuned damage calculations of the local approach resulted in a 157% increase compared to the initially calculated economic damages under the global approach.

With regards to economic sectors, the sectors most affected to this flooding event were Financial and Business Services (FBS; primarily due to Real estate belonging here, including most residential and commercial buildings), Wholesale, Retail, Transport, Accommodation & Food services, Information and Communication (WRTAFIC) and Industry. While Agriculture is a sector that can generally be considered as highly vulnerable to a flooding events, the relatively low share of Agriculture and the parallel relatively high share of Real estate- and Industry-related damages are all largely explained by the urban location of the investigated flooding event.

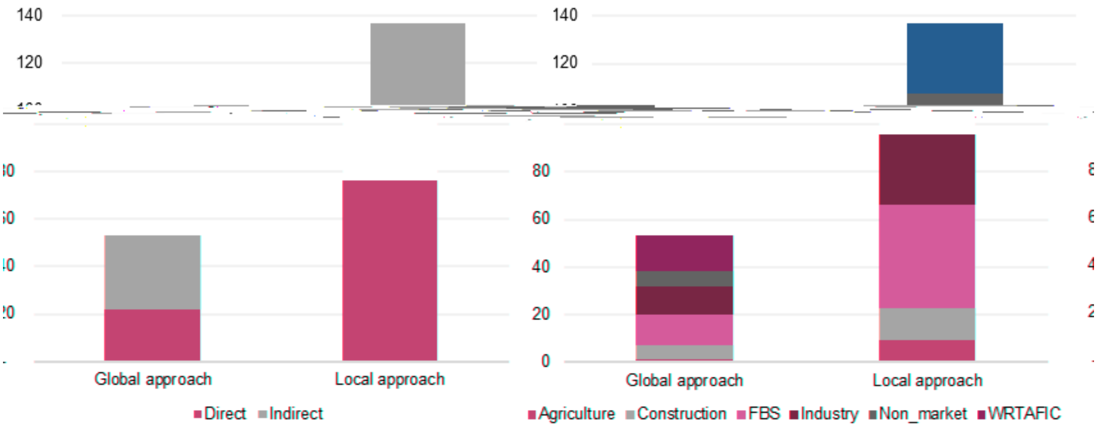


Figure 4.1 Change in economic output in CZ01 due to the flooding in Prague in 2013, comparison of global and local approach (m EUR 2010)

4.1.1.3 Results of the SCGE model, based on the local approach

The direct and indirect impacts for the Flooding in Prague are also analysed with SCGE model (for more information on the modelling exercise, see Annex 2).

Direct and indirect impacts on GDP: The negative effect of the extreme event is not being fully recovered in the medium-run and it looks like the region is ending up in a different lower growth path because part of the global investments is being relocated towards other regions and countries that were not hit by the extreme event and did not lose their productivity and productive capacity for a number of years (Figure 4.2).

The magnitude of the indirect effects is relatively small which is explained by the fact that the economy of Prague is dominated by services which do not have as large supply chain effects as the industry. Initially in the year 2013 the GDP of the affected region falls with about 0,05% and other the period of the following five year the level of the capital stock is recovered and the GDP growth between 2013 and 2020 is about 3,4%. However, despite the economic growth in this period the level of GDP remains lower than in the baseline scenario.

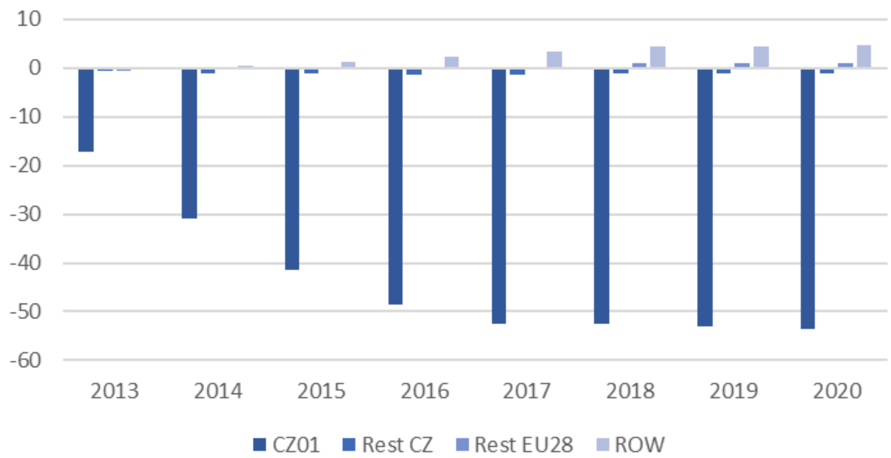


Figure 4.2 Medium-term direct and indirect impacts on GDP in millions of euros
[*Source: Own source. SCGE model*]

Sector-specific mid-term impacts: The most affected sector is the Agriculture followed by Industry and Other services sector that includes transportation that has been affected by the event (Table 4.2). The sector whose output is **positively affected by the extreme event in the years of the recovery process is the construction sector as well as the sector of non-market services.** The former is due to an increased demand for construction services that are needed to reconstruct buildings, plants, and infrastructure damaged by the extreme event. The latter can be explained by the fact that this sector provides services for households not only in Prague but also outside of this region.

Table 4.2 Sectoral development as compared to the baseline scenario, where baseline values are 100

	98,98	98,18	97,57	97,17	96,97	96,98	96,98	96,98
	99,91	99,85	99,80	99,76	99,75	99,75	99,75	99,75
	100,11	100,11	100,11	100,10	100,10	99,99	99,99	99,98
	99,92	99,85	99,80	99,76	99,75	99,75	99,75	99,75
	99,96	99,94	99,92	99,90	99,89	99,90	99,90	99,90
	99,98	100,00	100,02	100,03	100,04	100,09	100,09	100,09

Source: Own source. SCGE model

4.1.2 Analysis of the Windstorm Xynthia of 2010, Charente-Maritime

In 2010, several European countries were struck by a major weather depression, the Windstorm Xynthia. In France, this windstorm caused almost EUR 2,5 billion of damage (French Insurance Federation, 2011). The combination of strong winds and high tides resulted in a storm surge which caused major flooding in some coastal regions, mainly in Charente-Maritime, Vendée, and Côtes-d'Armo (Liberato et al., 2013). The region of Charente-Maritime has been selected for this case study as it suffered the highest number of damages (37,6% versus 16,4% in Vendée), including 12 fatalities (French Insurance Federation, 2011).

4.1.2.1 Comparison between the global and the local Damage Distribution Matrix

There are large differences[11] between the global DDM and the local DDM for windstorm Xynthia. However, one should keep in mind that the global DDM only reflects the damages from the storm and omits the damages from the flooding. In total there is a difference of around EUR 20 million difference between the global and local DDM for windstorm[12] (Table 4.3). As such, the global DDM deviates here 20% from the local DDM. Zooming in the distribution among the capital stocks, it shows that both DDMs allocate the largest share of damages to residential buildings and their contents (60% versus 45%) and to arable land (28%

percentage points more damages to this capitals stock than the global DDM. Despite their differences, it seems that overall, the two DDMs tell the same.

Table 4.3 Overview of the global and local DDM for windstorm Xynthia

	44.921	60%	41.573	45%
	0	0%	7.549	8%
	3.873	5%	7.966	9%
	3.873	5%	7.839	8%
	843.	1%	7.578	8%
	20.970	28%	20.881	22%

[11] The difference between to global and the local DDM totals 720.497 thousand of euros.

[12] The emergency costs are not included in the final numbers

However, there are several limitations that need to be considered (Annex 2).

- Several reports by the public authorities did not make a distinction between damages caused by the storm and damages caused by the flooding. As such, we used the share identified by the French Insurance Federation (2011);
- We were dependent on the documentation of the French Insurance Association and the public authorities. As such, there is risk that not all costs are included in our calculations.

4.1.2.2 Results of the I/O analysis: Comparison between the local and global analysis for the direct and indirect economic impacts

Similarly to the Czech Republic case study, the results of the economic impact assessment also increase re detailed data (Figure 4.3). The calculated economic damages (in terms of drop in economic output) due to the Xynthia windstorm are almost eight times higher under the local methodology than under the global approach for the total NUTS2 region Poitou-Charentes however, it is important to note that in the case of the Xynthia hazard event, the global methodology only accounted for the windstorm damages induced by the event, while the more sophisticated local methodology included both the windstorm damages and damages induced by the related flood event. The Xynthia event clearly had an impact on other regions and countries (other than NUTS3 region Charente-Maritime, as well,

indirect impacts.

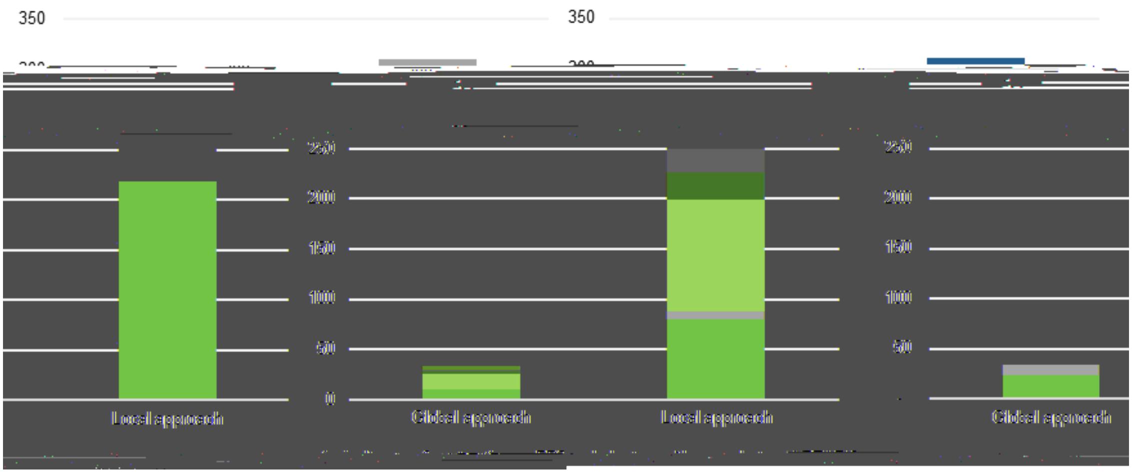


Figure 4.3 Change in economic output in Charente-Maritime due to the Xynthia windstorm in 2010, comparison of global and local approach (m EUR 2010)

This case study is a clear example on how a local event (albeit relatively large in terms of local economic damages, too) can impact total damages in that year for the whole ESPON area. When applying the damages of the local methodology for the Xynthia windstorm (and the related flooding event in the same area), there is an around 13% increase in total damages for the year 2010 at the whole ESPON area, direct and indirect economic impacts, aggregated[13].

With regards to the affected economic sectors, **the sectors mostly hit by this windstorm event (and the related flooding event) were Agriculture, Financial and Business Services** (FBS on chart; primarily due to Real estate belonging here, including most residential and commercial buildings), and Wholesale, Retail,

[13] Damages calculated in the local method are assumed to be larger on average than they are in the global method (due to more data and more types of damages accounted for). Also, they are considered to be more robust, as they are collected in a more sophisticated way of research than the global data taken from ready-made datasets. That being said, the global methodology alone most likely underestimates the real impacts of the disasters.

Transport, Accommodation & Food services, Information and Communication (WRTAFIC on chart). These sectors can be considered as most vulnerable to a future windstorm event in similar geographic area.

4.1.2.3 Results of the SCGE model, based on the local approach

The direct and indirect impacts for the Windstorm in Charente-Maritime are also analysed with SCGE model (for more information on the modelling exercise, see Annex 2).

Direct and indirect impacts on GDP: The negative magnitude of this extreme event is higher as compared to the flood in Prague due to higher damages. The Figure 4.4 shows that the negative effect of the extreme event is not being fully recovered in the medium-run and it looks like the region is ending up in a different lower growth path because part of the global investments is being relocated towards other regions and countries that were not hit by the extreme event and did not lose their productivity and productive capacity for a number of years. The magnitude of the indirect effects is again relatively small but somewhat larger as compared to the previous extreme event in Prague. Initially in the year 2013 the GDP of the affected region falls with about 0,2% and other the period of the following five year the level of the capital stock is recovered and the GDP growth between 2013 and 2020 is about 3,2%. However, despite the economic growth in this period the level of GDP remains lower than in the baseline scenario.

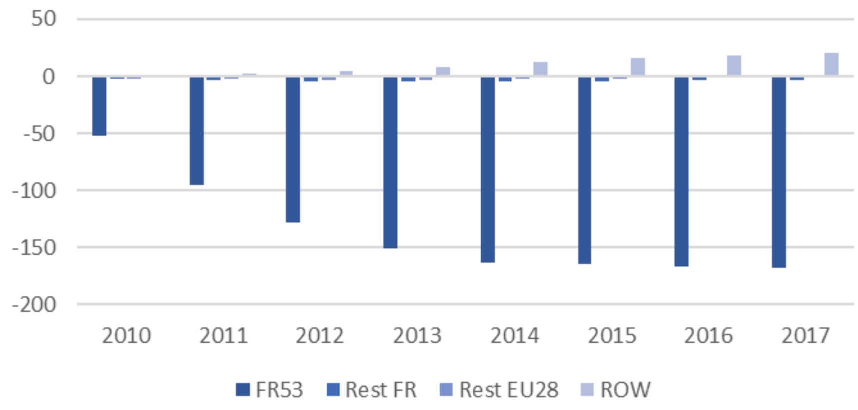


Figure 4.4 Medium-term direct and direct impacts on GDP in millions of euros
[*Source*: *Own source. SCGE model*]

Sector-specific mid-term impacts: the **most affected sector is the agriculture followed by industry and other services sector that includes transportation** that has been affected by the event (Table 4.4). The sector which output is **positively affected by the extreme event in the years of the recovery process is the construction sector and the non-market services** (for the same explanation as in the Prague case study).

Table 4.4 Sectoral development as compared to the baseline scenario, were baseline values are 100

	97,03	94,67	92,89	91,70	91,11	91,13	91,14	91,15
	99,91	99,83	99,77	99,73	99,71	99,70	99,70	99,70
	100,30	100,30	100,30	100,30	100,29	100,00	100,00	99,99
	99,64	99,34	99,11	98,96	98,88	98,87	98,87	98,87
	100,01	100,01	100,00	100,00	100,00	99,99	99,98	99,98
	100,01	100,08	100,13	100,16	100,18	100,24	100,24	100,24

Source: Own source. SCGE model

4.2 Policy relevance of local economic impact analysis

As a key observation, the results of the analysis carried out in the project enhance the need for better inclusion of local data in global data sets of natural hazard events. Once a large impact is assessed at global level for a specific event, a further refined/detailed local method should be applied. The policy-relevant implication is that the global methodology should serve a pre-screening purpose, in the sense that it should be best used to sense-check where further analysis is needed (i.e. events with initially high damages reported or events that have heavily affected certain sectors).

The two test case studies also provided insights in DRM (see Chapter 7 for a general view of all case studies). The case study of Prague shows that investments in flood defences reduce the overall damage costs and can play an important role in protecting vulnerable areas, such as historical centres and metro systems (Annex 2). After the heavy and costly flood in 2002 (approximately EUR 1 billion of damage costs), the city of Prague invested millions of euros in adaptation measures consisting of flood protection measures and disaster response management (Lorencová et al., 2016). Although the flooding in 2013 had different characteristics than the flooding in 2002[14], one could say that the flood protection measures worked well as the essential areas such as the historical centre and the metro system were mostly protected during the flood (compared to the flooding in 2002). As such, the difference in damage costs between the two floods is EUR 794 million. Extracting the investment costs[15] in flood protection measures from this numbers, results [16].

In the case study of Charente-Maritime (but also the surrounding regions), the dikes and dunes were not able to prevent the flooding. In some cases, the dikes were too low (for instance near La Faute-sur-Mer and Aytré) however in other cases the dikes fail (e.g.: Île d'Oléron) (Slomp, 2010). It was also reported that water entered the villages from behind the flood defences (Annex 2). Analysts report that the flood defences were probably built (on past flooding experience) so for a hundred-year return period (which does not reflect the intensity of the Xynthia storm surges) (Slomp, 2010).

[14] E.g.: intensity of the floods cannot be compared as the flood in 2002 is classified as a flood with a return period of 200 to 1.000 years (at some locations even >1000), whereas the flood of 2013 had a return period of 20 to 50 years (with a few

caused by the smaller rivers (interview data).

[15] The mitigation and adaptation costs were calculated to be around EUR 154,3 million.

[16] Note that this is a simplified calculation. However, the number does illustrate how important flood protection measures are in reducing the damage costs.

5 Territorial Vulnerability to Disasters caused by Natural Hazards

Vulnerability matters. The vulnerability helps us understand why the occurrence of a natural hazard become a disaster. The most vulnerable territories to disasters, according to the methodology used in ESPON-TITAN project, are located in Eastern Europe, Southern Europe and Baltic Region.

Disasters are not equally distributed among different territories. For the same level of hazard, the impact of disasters can vary considerably, which is explained by differences in vulnerability and exposure. The vulnerability of a territory is complex, depending on multiple dimensions like social, economic, demographic, environmental and governance (Blaikie et al., 1994; Birkmann, 2013). Regarding the scale and coverage, this analysis has been performed at NUTS3 level and it covers the 32 countries from ESPON Space.

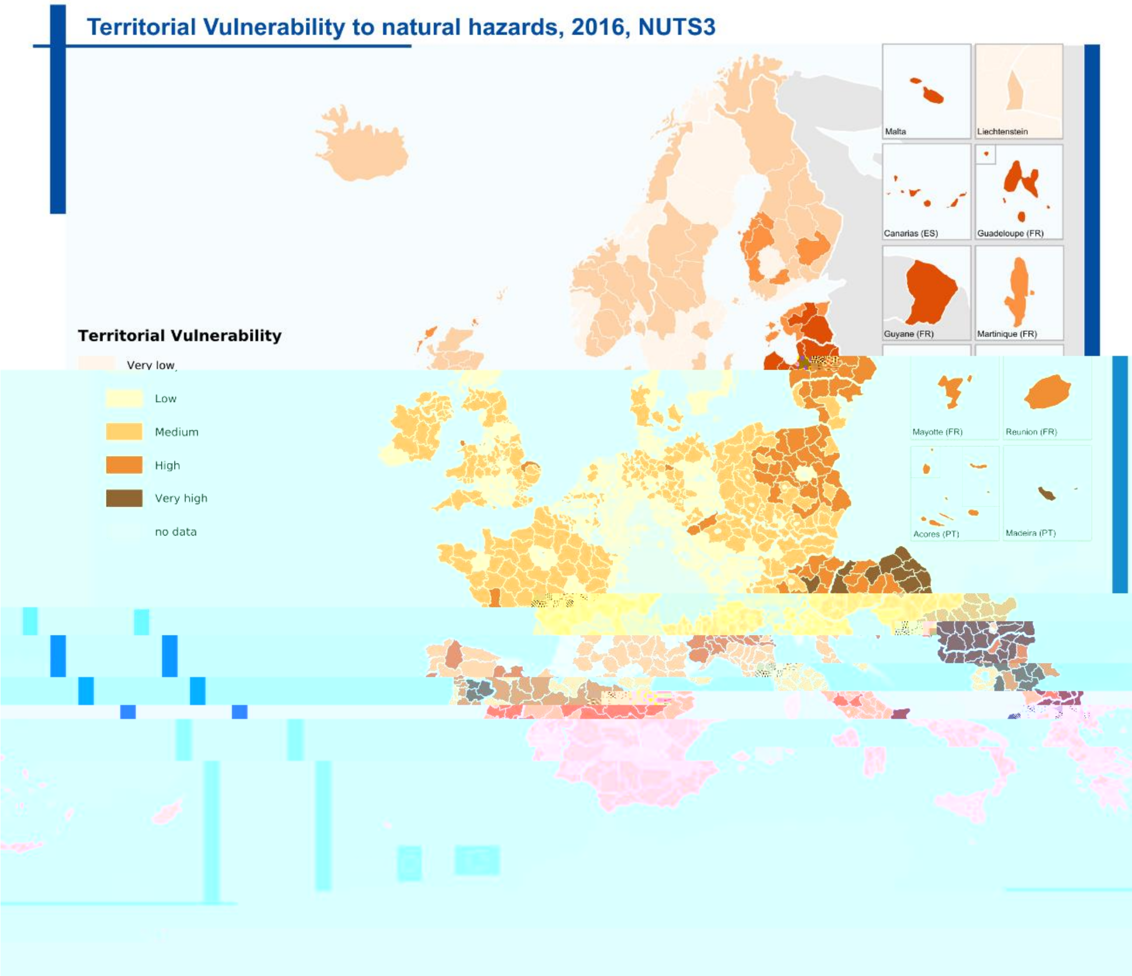
5.1 Assessing Territorial Vulnerability

As described in the ESPON-TITAN conceptual framework (section 1.1), in order to perform a risk assessment, the three components: hazard, exposure and vulnerability shall be considered. In turn, vulnerability is disaggregated into two other elements, namely susceptibility and coping capacity. Therefore, this specific section is scoped on the analysis of the territorial vulnerability, and so is centred on analysing indicators that help to understand and illustrate different vulnerable territories in Europe.

This territorial vulnerability assessment requires a holistic and integrative approach, due to the multiple dimensions involved, all contributing to territorial dynamics and thus spatially represented (demography, education and research, economy, environment, social capital and perception, health, gender and governance). In this regard, this assessment considers 25 in /Span <</MCID 5/Lang (en-GB)>> BDC 5(t)11(h)-3r3.95 Tm0 g0 G[(

	Demography	Natural population change	Crude rate of natural change of population
	Demography	Migration rate	Crude rate of net migration plus statistical adjustment
	Education and research	Tertiary Educational Attainment	Tertiary Educational Attainment of population between 25-64 years old
	Education and research	R&D expenditure	Research and development expenditure as percentage of GDP
	Education and research	R&D personnel and researchers	Research and development personnel and researchers as percentage of total employment
	Education and research	Patent applications to the EPO	Patent applications to the European Patent Office (EPO) per million inhabitants
	Social capital and perception	Social capital	Social capital as a combination of social trust, social support and participation
	Social capital and perception	Risk perception	Aggregated value of perception of droughts and floods importance, perception of climate change importance, and budget prioritization by population for climate change and environmental protection
	Health	Hospital beds	Number of hospital beds per 100 000 inhabitants
	Health	Practising physicians	Physicians or medical doctors per 100 000 inhabitants
	Economy	GDP per inhabitant	Gross domestic product (GDP) per inhabitant
	Economy	Professional, scientific and technical employments	Percentage of professional, scientific and technical jobs
	Environment	Spatial distribution of GI	Spatial distribution of Green Infrastructure
	Environment	Potential GI network for CC&DRR policies	Potential Green Infrastructure network serving the purposes of CC and DRR policies
	Gender	Gender equality index	Index developed by the European Institute for Gender Equality (EIGE) that considers work, money, knowledge, time, power and health domains
	Governance	Quality of Government index	This index focuses on both perceptions and experiences with public sector corruption, along with the extent to which citizens believe various public sector services are impartially allocated and of good quality in the EU
	Governance	Municipalities signatories to the Covenant of Majors	Weighted share of municipalities that have signed the Covenant of Majors and have also submitted an Action Plan

The methodology to obtain the vulnerability is based on multivariate statistical techniques, specifically Principal Component Analysis (PCA), which is widely used in vulnerability assessments (Cutter et al., 2003; Fekete, 2009; Tapia et al., 2017) (see Annex 3). Map 5.1 shows the spatial territorial vulnerability pattern in relative terms for 2016 and at NUTS3, in the ESPON space.



Map 5.1 Territorial vulnerability to natural hazards, 2016, NUTS3

A spatial distribution can be observed whereby the territories to the east and south are more vulnerable to natural hazards. Certain areas in Hungary, Romania, Bulgaria, Greece, Italy, Spain and Portugal outstand. Nevertheless, some territories in Estonia, Latvia, Lithuania, Poland, France, and Czech Republic are also significantly vulnerable.

The most vulnerable territories have a high susceptibility, as shown by indicators of: Early leavers from education and training, Unemployment rate and risk of poverty and Social exclusion. They also have a reduced coping capacity, as shown by indicators of: R&D expenditure, R&D personnel and researchers, Patent applications to the EPO, GDP per inhabitant, Professional, scientific, and technical employments, Social capital, Gender equality index and Quality of governance.

In addition, it contributes to understand the results the analysis of the population volume living in those territories Figure 5.1 shows the population (Eurostat, 2016) in each vulnerability group by country. In total, the population living in territories with high or very high vulnerability sums 116 out of the 528 million in total, accounting for 22%. By country, Romania, Italy, Bulgaria and Greece are the ones with more population in highly vulnerable territories, followed by Spain, Portugal, Hungary, Poland and France.

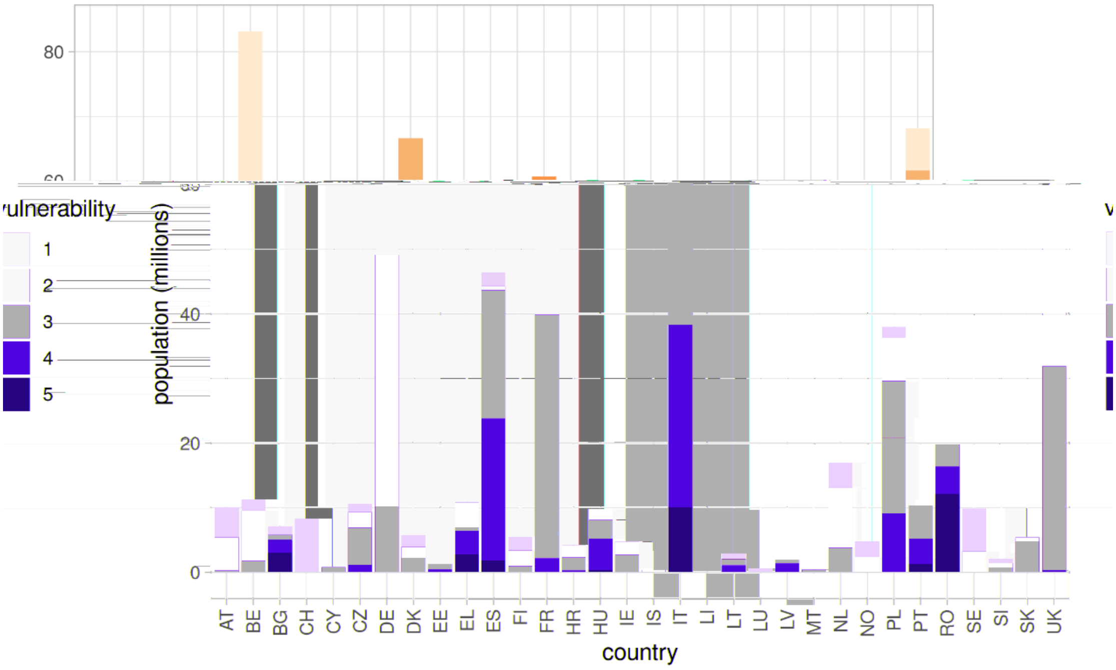
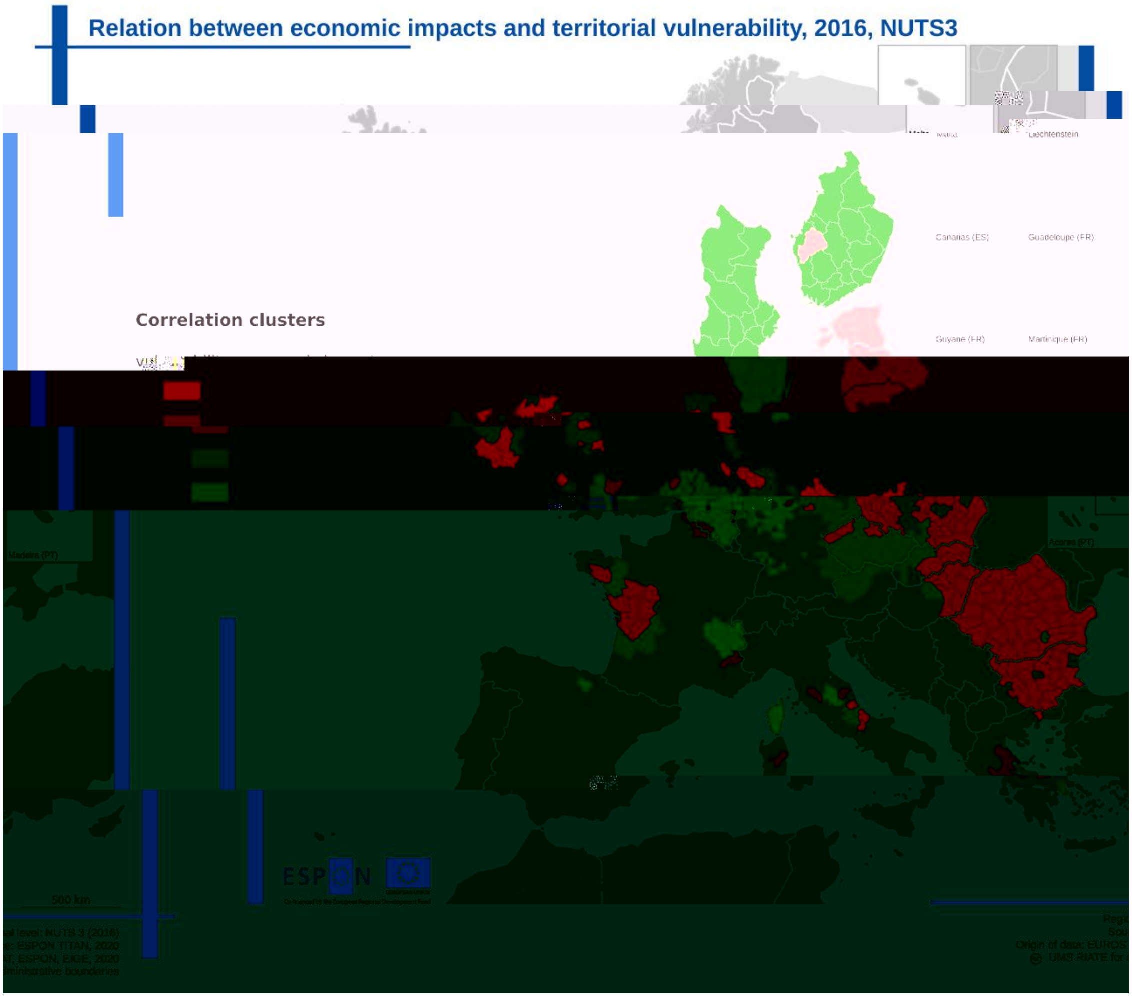


Figure 5.1 Population living in vulnerable territories

It is worth mentioning that the vulnerability assessment performed in ESPON-TITAN project is done from a DRM perspective, while the one developed in the framework of the 2013 ESPON CLIMATE project is based on a CCA perspective. ESPON CLIMATE was based in the previous IPCC framework where the exposure is considered as a component of vulnerability, whereas the fifth IPCC report (IPCC, 2014) propose a risk framework in line with DRM community, where the risk is a combination of hazard, exposure and vulnerability, as previously mentioned. In this regard, the current assessment provides an updated version in terms of: (i) approach, following the current state of the art which aligns disaster risk assessment and climate change risk analysis, in which the exposure is not a component of vulnerability; (ii) new indicators are considered about governance, social capital, risk perception and gender; and (iii) more updated data from 2016.

Comparing the vulnerability results in both projects, in terms of spatial distribution, they both highlight Romania, Bulgaria, Greece, Italy, Spain and Portugal as countries with highly vulnerable territories. On the other hand, the greatest differences are found in Estonia, Latvia and Lithuania, where vulnerability is relatively high in the new assessment compared to that obtained in the 2013 analysis. These differences might be explained by the updated approach, where the exposure is not included in the vulnerability analysis, as well as by the inclusion of new indicators.

Additionally, the relation between economic impacts and territorial vulnerability has also been analysed (Annex 3). Map 5.2 shows the relation highlighting only those areas with high significance.



Map 5.2 Relation between economic impacts and territorial vulnerability

According to the distribution presented, a certain correlation between economic impacts by GVA and territorial vulnerability can be deduced. The areas in strong red are a cluster of territories where both the vulnerability and the economic impacts are high. Whereas in strong green, they are clusters of territories with both low vulnerability and low economic impacts.

Finally, as a means of validating these results, a spatial regression model of past economic impacts has been performed (Annex 3). In this model, the dependent variable is the economic impacts and the independent variables are the hazards (flood, windstorms, earthquakes and droughts), the exposure (GVA) and the territorial vulnerability. The model is calibrated against past economic impacts and its explanatory capacity is analysed. The comparison between the spatial distribution of past economic impacts and the output of the spatial regression model shows a relatively good agreement. Therefore, it can be concluded that the hazard assessment and the territorial vulnerability analysis performed in the project are relatively successful at explaining the past economic impacts.

5.2 Policy relevance of vulnerability analysis

Knowledge of territorial vulnerability patterns is crucial for proper disaster risk management. It allows the orientation of actions towards the most vulnerable regions, prioritizing those that could be most affected by the occurrence of an extreme natural phenomenon.

In this sense, territorial planning has a key role in DRM due to the fact that its practice is closely linked to several vulnerability components, and therefore has the potential to balance existing vulnerability inequalities between territories.

In addition, as it was already mentioned in previous sections, regarding economic impacts, a clearer orientation on vulnerability reduction could be an efficient way to reduce impacts of potential disasters. Moreover, tackling the vulnerability factors (e.g. education, hospital beds, etc.) would have substantial co-benefits in addition to the reduction of vulnerability to natural hazards.

6 Instruments on Disaster Risk Management and Climate Change Adaptation

At the EU level, as well as on the national levels of the ESPON countries, several instruments exist regarding DRM and CCA and some good practice examples can be identified. Although progress has been made especially in risk assessment, the practice of DRM and CCA is still far from fulfilling the requirements for an effective spatial, risk-oriented management approach that includes also the multiple dynamics of changing hazards, exposure and vulnerability. The research indicates that the effectiveness of instruments can be tackled by supporting innovations in the assessment, as well as supporting the implementation of instruments.

The presented findings are based on a multi-methodological approach. A desktop analysis, which focused on existing studies on DRM and CCA practices in Europe was combined with primary data from the case studies analysis (document analyses and expert interviews). Results include a summary on the practice of DRM and CCA (Annex 4), with a focus on the state-of-the-art in risk assessment and climate impact assessments as an evidence basis for management actions. Risk management and climate adaptation practices encompass spatial planning measures as well as innovative approaches, such as residual risk management through disaster management plans and procedures. Some good practices collected on the inclusion of innovative governance structures for DRM and CCA into spatial planning (Annex 4) may illustrate some of the conclusions presented. As it will be seen, the crucial role of EU directives and their potential to support good and effective practice of DRM is considered.

The deepening of the analysis through case studies allowed the identification and description of successful cooperation mechanisms, qualitative contexts of DRM and CCA, and an estimation of effectiveness of policies and instruments, which are always context-dependent due to the heterogeneity of legal-administrative systems and cultural settings throughout Europe. Some good practices were acknowledged from the interviews with local stakeholders. However, detailed aspects of risk mitigation through structural works and adaptation of buildings and infrastructure, to make them more resistant to the disaster effects, were only touched partially in the case studies.

6.1 Practice of DRM and CCA

The main objective envisaged in this working step was the identification of instruments and tools (predominantly in spatial planning/territorial development) for DRM and CCA measures as well as the assessment of their benefits and usefulness. Annex 4 shows literature and an analysis of DRM and CCA practices in the ESPON countries for flood, storm, earthquake, drought, and other selected hazards, structured along with the criteria of risk assessment, risk management, climate change assessment and CCA as well as good practice examples. Derived from this collection and supported by the results from existing meta-studies the following non-exhaustive findings regarding the practice of DRM and CCA in Europe were made.

6.1.1 Risk assessment

According to an earlier communication of the European Commission (EC), it was already confirmed in research projects and publications that risk mapping is complex and gaps remain in the methodologies. Although hazard mapping was considered to be improved (especially because of the wider use of GIS techniques), the creation of risk maps by including social, economic and environmental variables was still a challenge (EC, 2010). However, in recent years, the submitted National Risk Assessment (NRAs) has shown JRC report on recommendations for NRAs for DRM. Based on this review, they conclude that in these assessments, the spectrum of hazards and threats addressed have been continuously enlarged, that climate change is included and interactions among hazards are considered, that a long-term prevention-oriented planning perspective complements the short-term reactive perspective and a stronger involvement of research eem to completely overcome the deficits that were identiefied in the report from 2019, such as the low coverage of the dynamic nature of risk, the change of risk factors, and how the assessments support DRM planning and finally action. Also, the recommendation to enhance quantitative approaches in order to replicate and

As ESPON has an explicit territorial approach it is important to take a territorial or spatial perspective on risks. Considering the spatial risk context means to go beyond sectoral risk assessment approaches and consider the entirety of risks that exist in an area, calling for multi-risk assessment and management. An assessment of recent research activities, however, shows that so far multi-risk perspectives are not systematically addressed among disaster risk management approaches in EU countries and that single-hazard maps are still the decision support tool most often used. The authors further conclude that barriers to implement multi-risk assessment into DRM are found in science and practice, resulting in a general lack of integrated practices for multi-
that aim at a multi-hazard perspective in risk assessment (e.g.: Austria, France, Italy, Switzerland) rather overlay layers of various hazards that really integrating hazards by assessing (modelling) interdependencies and effects due to the accumulation of hazards (see Annex 4 and individual case studies´ reports).

A decisive point regarding the effectiveness of DRM is how information on natural hazards (i.e. the results of hazard assessment) is used to inform decision making and especially how spatial information about hazards are integrated into the spatial planning process. In principle, there are the three types of primary integration, secondary integration and informative support (Table 6.1).

Table 6.1 Types of integrating spatial hazard information into the spatial planning process

Description	Consideration of the hazard prone areas during the compiling or review of the local land-use plan (informed, e.g. by Strategic Environmental Assessment; examples: Finland, Poland, Germany with the exception of river floods).	The hazard zones are displayed as a separate map which (partly) are mandatory to be considered in land-use planning (examples: Austria, France, Italy, Switzerland, Germany in the case of river floods).	Definition of hazard zones within the scope of expert planning – objections may be raised to decisions that are made on this basis. Independent hazard maps or hazard zone plans without obligation to include them in land-use plans (examples: Germany in the case of alpine hazards, France, Greece, UK).
Advantages	Risk communication is integrated into the public consultation process. At the local level, no additional instruments are needed; hazards are weighed-up against other concerns and interests.	Hazards are treated according to uniform principles in all municipalities. Definition of hazard zones can be applied directly in building approval procedures. -No “weighing away” possible.	Changes to hazard zone and land-use plans can easily be made.

A comparative overview of the characteristics of national risk assessments as well as the criteria to describe probability/likelihood and impact/consequences of disasters is provided in the Commission Staff Working

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(EC, 2017:68).

6.1.2 Risk management

Risk management approaches vary considerably among the European countries, too. In their comparative analysis for the Committee of Regions on the implementation of the Sendai Framework at the EU level the

systems that manage the different national civil protection m

However, disaster risk management can be broadly grouped as follows (CoR, 2016a):

- Decentralised management with legislative competence: Austria, Germany, Spain, Italy;
- Partially decentralised management: Belgium, Bulgaria, Czechia, Denmark, Greece, Finland, France, Croatia, Ireland, Latvia, Netherlands, Poland, Portugal, Romania, Slovenia, Sweden, Slovakia, United Kingdom;
- Primarily centralised management: Cyprus, Estonia, Hungary, Luxembourg, Lithuania, Malta.

In many European countries disaster risk management still is ineffective because coordination and

that a robust and flexible governance model in which one authority has the mandate to coordinate all parties involved is essential. Further, any kind of risk management or governance shall enhance coherence across sectors and create a working environment based on the same set of evidences. E.g., risk should be assessed in collaboration with stakeholders, including those on central and regional levels of government and

disaster risk, in the lates report on

prioritise the development of national risk assessment capability and to base this on regular risk management capability assessments (RMCA). RMCAs can support a sustainable development of capabilities for the implementation of an integrated DRM, as well as a continuous adaptation to changes of risk profiles (e.g.: due to climate change or other new and emergent risks).

6.1.3 The example of flood risk

ESPON-TITAN has chosen river flood, drought, windstorm and earthquake risks to be analysed throughout the ESPON space. However, only for flood risk management, an EU directive (with the requirement to implement it in national legislations) exists. Thus, flood risk is the hazard that is most advanced in terms of a European-wide harmonised risk assessment and management due to the coming into force and implementation of the Flood Risk Management Directive (FRMD) since 2007. Therefore, the example of flood risk can ideally serve to compare advances and challenges of disaster risk assessment and management from a European perspective. In their report on the implementation of the FRMD, the authors identified overall positive effects, especially improvement of coordination between the Commission and the Member States, progress in the assessment of flood risks, consideration of previous work, including existing long-standing cooperation between the Member States as well as activities to raise flood awareness among citizens in Member states (ECA, 2018).

On the other hand, the team of auditors (ECA, 2018) found still existing weaknesses: weaknesses in allocating funding, insufficient funds for planned flood-related action, and limited funding for cross-border investments, generally not quantified or time-bound objectives (especially commonly agreed protection goals) in the flood risk management plans, weak linkage of project ranking procedures to the priorities in the FRMPs. They thus recommend improvements in data provision, cost-benefit analyses and models to design projects, better coordination of the implementation of the FRMD and Water Framework Directive (WFD) and supporting the implementation of green infrastructure projects as they have multiple benefits (ECA, 2018).

As major challenges for the future the auditors identified the lack of up-to-date knowledge on the likely impact of climate change on the incidence of floods, the practice of using statistical data from historical events for determining frequency-magnitude relationships, which carries the risk of not reflecting climate change, where applicable, private flood insurance coverage is still low and regarding land-use and spatial planning regulations to mitigate flood risk they conclude that Member States still had more to do (ECA, 2018).

6.1.4 Integration of climate change and other issues in disaster risk management

Although climate change impacts are not analysed in ESPON-

Table 6.2 Consideration of climate change, cross-border risks and cascading effects in National Risk Assessments (as of 2017)

			-					
Austria								

6.2 The role of EU Directives and their potential to support DRM practices

The research on hazards, vulnerability, economic impacts, and DRM and CCA instruments performed in ESPON-TITAN is embedded in a wide set of legislative, scientific, informative and financial activities that have been initiated at EU level in order to support policies that follow resilience building and disaster risk reduction. Not all of these activities directly refer to DRM and CCA, but many have indirect effects and factual interrelations.

One of the recent documents and initiative is the **European Green Deal** (EC, 2019), which aims at a

the European Green Deal and reference to disaster risk is made with regard to ecosystems that contribute to mitigating natural hazards, as well as to rural and remote areas and their vulnerability to climate change and natural hazards.

Other, is the new **EU Strategy on Adaptation to Climate Change** (EC, 2021) that, among others, aims at a faster adaptation process and suggests to create synergies with broader work on disaster risk prevention and reduction, and to strengthen climate considerations in EU disaster risk prevention and management. Further, the financial system is seen as an important element to increase resilience to climate and environmental risks (especially those arising from natural catastrophes).

In addition, the proposed **European Climate Law** (EC, 2020) aims at reaching the goals set in the European Green Deal, and introduces requirements for national climate change adaptation strategies, which should

Disaster risk reduction can be further promoted by these new policies, especially by building stronger interlinkages between CCA and DRM frameworks. However, also can be previous policies and the implementation of **EU Directives** in Member States, that have strongly improved spatially oriented disaster risk management and risk reduction.

6.2.1 EU Directives with references to preventive risk management

In the past, important impulses for preventive and spatially oriented risk management in the EU member states came from EU legislation, as the EU-wide Directives require national legislation to be adapted. From the point of view of preventive risk management in spatial planning, especially the FRMD (2007/60/EC), the SEVESO III Directive (2012/18/EU) and the amendment of the Environmental Impact Assessment (EIA) Directive 2014/52/EU (EU, 2014a) are of importance. The ECI Directive 2008/114/EC (EC, 2008) for the protection of European critical infrastructures also shows clear references to preventive risk management. Other directives, such as the Infrastructure for Spatial Information in the European Community (INSPIRE) Directive 2007/2/EC (EC, 2007a) do not directly or only partly show connections to preventive risk management but can potentially take care of a strong support of DRM and CCA:

The **Flood Risk Management Directive** was implemented in the national laws of the member states from 2010 on. This paved the way for better coordination of flood prevention in the European, often cross-border river catchment areas. The guideline also strengthened integrated flood prevention, which focuses on managing risks rather than just protecting flood-prone areas against flood hazards (BMVI 2017.

In view of the high potential for damage, in the event of a disaster, facilities that are inherently hazardous (hazardous installations) increasingly come into focus. With the amendment of the **SEVESO III Directive** 2012/18/EU (EU, 2012), the references to land policy and land-use planning were strengthened. This also addresses cascade effects caused by endangering companies, for example in the event of flood disasters.

The amendment of the **Environmental Impact Assessment Directive** 2014/52/EU (EC, 2014a) makes the consideration of climate change and disaster risks a mandatory statutory task, as projects are related to carrying out an EIA. The EIA report has to include the impact of the project on climate as well as the vulnerability of the project to climate change. These aspects may have to be considered in a future amendment of the Strategic Environmental Assessment Directive (2001/42/EC) as well because also designated land-uses laid down in plans and programmes can be vulnerable to hazards and climate change.

6.2.2 Potential of EU Directives to support good and effective practice of DRM

et al., 2017, 2019, 2021; ECA, 2018) describe criteria that should be met in order to carry out a sound and **effective DRM** be it on the national, regional or local level. These criteria can serve as a general assessment scheme but at the same time as selection criteria to define **innovative policies and instruments** and **effective practices**. According to the documents analysed, a list of the most relevant criteria was collected. Table 6.3 shows these criteria and relates them to the EU directives described above in order to comment on issues already addressed by the directives and potentials for future consideration within the directives (or future amendments of these).

Table 6.3 The role of EU directives and their potential to support good and effective practice of DRM

Provide data: the provision of comparable, standardised and up to date data is a cornerstone for any risk assessment	INSPIRE	INSPIRE directive could be extended to more small-scale and standardised/ harmonised data regarding hazards and risks
Collaborative approach across sectors: involve experts from different research communities (natural hazards, socio-economic, policy-oriented) and take care of harmonised assessment approaches	FRM directive: requirement for an active involvement of interested parties regarding flood risk plans EIA directive: requirement to involve experts from different communities	
Vulnerability data: take into account socio-economic data (especially elements that need to be protected) in order to assess risk and diversify management options	FRM directive: risk maps	
Multi-hazard risk assessment: consider, overlay and integrate relevant hazards and risks within a territory	Not directly addressed by EU directives, but implicitly covered by EIA Directive	
Tools for prioritizing and for risk mapping: Provide for and support stakeholders in selecting relevant hazards and producing robust risk maps	FRM directive: hazard and risk maps	
Consideration of critical infrastructures: these are especially vulnerable but can at the same amplify risks within the system	ECI directive	ECI directive with potential to extend the protection-oriented approach to a systemic resilience approach
Consideration of cascading effects: based on the inter-relation between sectors and activities the identification of cascading or domino effects	SEVESO III directive (but only for establishments addressed by this directive)	
Parallel modelling approach: Consider time and dynamics of hazards and vulnerabilities in the assessment concept	EIA directive (amendment), requirement of assessment against baseline scenario (indirect consideration)	FRM directive: these dynamics could also be considered in hazard and risk maps
Scenarios of future development: working with scenarios helps to think of possible futures, even in settings of uncertainty but at the same time to consider future changes (e.g. due to demography, economic structural change or climate change) as well as potential extreme events (e.g. very unlikely events, failures of protection measures etc.)	EIA directive (amendment), requirement of assessment against baseline scenario	

Provide quantitative results in order to allow comparability across sectors, territories and time	Not addressed by EU directives	
Provide results in maps: show the levels and natures of risk, different for each return period (or annual probability or likelihood) and hazard type (e.g., a GIS map of the potential impacts) in order to show the spatial extent of risk	FRM directive	
Regular update of assessments	FRM directive	
Coordination of all involved stakeholders	FRM directive: coordinated management plan within one catchment area/river basin	
Primary integration of risk assessment and management into spatial planning processes: hazards and risks that are already integrated in spatial plans call for a more effective DRM than a secondary integration of sectoral hazard and risk maps	Not addressed by EU directives	Strategic Environmental Assessment (SEA) directive amendment could take care of this aspect
Territorial approach: identify management options that mitigate risks in the whole territory instead of following unconnected sectoral approaches	Not addressed by EU directives	
Innovative strategies (no regret strategies; retreat; burden sharing)	Not addressed by EU directives	
Specific sectoral management plans and instruments	FRM directive: management plans	
General:		
Stakeholder involvement: increases the quality and acceptance of risk assessment and risk management (involvement already in the development and selection of methodologies)	FRM directive, involvement of interested parties	
Integration of climate change in DRM and closer cooperation between DRM and CCA action and concepts	Not addressed by EU directives	
Cross-border assessment and management initiatives	FRM directive, assessment and management according to river basins and not Member States or other administrative units	

6.3 Policy relevance of DRM and CCA instruments analysis

At the EU level as well as on the national levels of the ESPON countries several instruments exist regarding disaster risk management and climate change adaptation. In both cases various initiatives, approaches and experiences exist and some good practice examples can be identified (Annex 4). However, the practice of DRM and CCA is still far from fulfilling the requirements for an effective spatial, risk-oriented management approach that includes also the multiple dynamics of changing hazards, exposure and vulnerability.

The research indicated that as a main message the challenge of improving the effectiveness of instruments can be tackled from two directions:

- Support innovations in assessment to inform decision-making and use of instruments by considering criticality and cascading effects (especially for DRM), aiming at a parallel modelling approach (especially for CCA) and improving the comparability of assessment methods (granularity, data, approach);
- Support the implementation of instruments by a further development of supporting instruments such as SEA directive (integration of DRM/CCA perspectives) or contingency plans that bring together different actors as well as acknowledging the high relevance of soft instruments (provide environments where experts and decision-makers learn from each other, support of trust-building measures, horizontally and vertically).

The juxtaposition of good and effective practice of DRM and the existing EU directives shows that the FRM directive occurs and thus contributes to many of these requirements. Thus, it becomes clear how much the FRM directive initiated in terms of increasing effectiveness of DRM in Europe. The question, however, is if

7 Understanding Practice in Context

ESPON-TITAN has investigated **8 case studies** (Figure 7.1) that represent different spatial, institutional and governance settings and that range from local to regional scale in a homogeneous geographical distribution. They aim to illustrate the findings in terms of natural hazard distribution, associated economic impacts and policy instruments in comparison to the analyses made for the European level (see Chapters 2-6), and to contribute to the generation of policy recommendations focused on a better integration of DRM and CCA in Spatial Planning (see Chapters 8-9). The analysis has given deeper insights into the variety of the spatial patterns of natural hazards and their consequent territorial and sectoral impacts, at the same time that the results have allowed to identify different measures, considering not only DRM and CCA, but also the existing types of cooperation and coordination between actors and territorial levels, that somehow influence the effect of disasters.

For that, stakeholder consultations were conducted, in order to obtain a local perspective on practice of DRM, implementation of CCA measures, relation to spatial planning, existing coordination and cooperation among entities beyond the formal planning process, lessons learned, among other local particularities.

Figure 7.1 ESPON-TITAN Case studies

As showed, the selected cases studies are:

- **Alpine Region** (including Germany, Austria, France, Italy, Liechtenstein, Monaco, Slovenia and Switzerland), focused on cross-border/macro-regional scale cooperation and coordination.
- **Andalusia (ES)**, focused on the regional-scale floods and droughts, as the main hazards to which it is vulnerable.
- **Dresden Region (DE),** focused on flood risk management on the regional scale and vulnerability due to population density.
- **Nouvelle-Aquitaine region (FR)**, focused at a regional scale, on the Xynthia storm occurred in 2010 that severely affected the region due floods, sea water entrance to inlands, dunes erosion.
- **Lombardy Region (IT)**, focused on landslides and flooding in the broader territorial context of the Po river basin.
- **Pori city (FI),** focused on the city area at the local scale.
- **Prague (CZ)**, focused at a regional scale, on the Central European Floods occurred in 2013 that severely affected the region.
- **Rotterdam city (NL)**, local scale case study, focused mainly on their experience on management of pluvial flooding and subsidence.

7.1 Hazards and economic impacts at regional and local scales

In general terms, flood risk outstands among all the analysed hazards (droughts, windstorms, and earthquakes, and in some cases, landslides). Floods appear as the main hazard that affects most of the case studies. Critical floods were analysed in Rotterdam and Prague, with important damage and losses. As expected, it is also the main cause of direct and indirect economic impacts both at rural and urban areas. As stated in ESPON-TITAN findings (Annex 1), and confirmed by the case studies, floods combine short-terms events (usually less aggressive but more frequent, e.g. in case of floods of 10-, 20- or 50-year annuities, HQ_{10}, HQ_{20}, HQ_{50}) with long-term ones (more dangerous but less frequent, although usually more intense, e.g. in the case of 100- or more years annuities, including extreme flood events, HQ_{100} $HQ_{extreme}$).

The cascading effects of hazards is common, and much clearer when analysed at a regional and local scale e.g., higher temperatures increase droughts, leading to stronger and concentrated-in-time windstorms (in turn, emerging floods). A typical phenomenon consequent of this cascading effect are landslides, triggered by floods and storms, and especially tacked in the Lombardy case study, given its high frequency and damages produced. These situations reinforce the need for considering a systemic (integrated and multi-scalar) perspective on the formulation of DRM and CCA measures, in order to provide a better understanding of the existing dynamics and relations of hazards, and to be able to propose alternative solutions in the short, medium and long-term.

The analysis of economic impacts of the disasters is a practice not regularly done in the investigated case studies, and less if considering the achievement of a monetized value. In all cases, there is an exercise on estimating direct damages and losses after an emergency has occurred (e.g. as a basis for applying financial support from the national and/or European level). However, indirect impacts are rarely considered, given some constraints to reach a value estimation. In the cases where it happens, it is usually performed by an external entity, often from research/academia and not necessarily related to administrations within the affected areas.

ESPON-TITAN has thus, based in the global economic impacts methodology (Chapter 3), performed a local analysis in two of our case studies (Chapter 4): Prague, heavily affected by the Central European Flood in 2013; and the region of Nouvelle-Aquitaine, in which the effects of the Xynthia storm were devastating. The comparison of the local and global results was presented (Chapter 4), which conclusions clearly indicate that scale matters in terms of the precision of data used.

Besides, climate change may amplify the magnitude, frequency and even the territorial patterns of certain natural hazards and thus lead to higher impacts. That is where the importance of considering the simulation of future scenario resides. A proper planning, considering possible future extreme events, may improve the preparedness and adaptation of a region to climate change, consequently, minimize costs of a possible recovery.

7.2 Integration of DRM and CCA at regional and local scales

According to ESPON-TITAN case studies analysis, and based on overall experience, the integration of DRM and CCA measures into spatial planning is an effort that may result in a better adaptation of the affected areas to natural hazards, decreasing disaster recovery costs. For that, the administrative structure must allow the coordination, and territorial and sectoral planning responsible must be coordinated, work in collaboration having in mind this holistic view.

Some of ESPON-TITAN case studies are part of countries that present a more centralized administrative structure (Finland, the Netherlands, France, Czech Republic), while others, a decentralized organization, with some political power at regional level (Spain, Italy, Germany). This structure usually determines the spatial planning system and shapes the responsibilities and competences among different administration levels.

The **administrative structure** in all cases are divided into (1) a national government, represented by the State; (2) a regional government which in countries with a decentralized organization, usually have high decision power on planning matters (3) sometimes an intermediate level between regional and local

most frequent situation in terms of **planning system** is that a national framework exists that establishes legally binding targets that must be followed in regional and local plans (in decentralized organization, planning competences are domain of regional authorities, such as in Andalusia). Land-use plans are developed at a municipal level in all cases. Either spatial planning is formulated at national or regional administration, in most of the cases they are not fully coordinated with sectoral plans, which may constitute an evident weakness when aiming to integrate DRM and CCA measures.

Spatial planning and sectoral planning, in the matter of natural hazards, are two spheres of instruments that should be closely related. The first should include measures to correct and prevent risks, that in turn should be identified and included in sectoral plans, independently of who is the competent entity or who is responsible for the assessment, that ideally should be multi-departmental. DRM and CCA are two fields of action that are key to prevent disasters and to better manage natural hazards, and both should establish criteria to be collected in spatial planning. However, not all case studies present neither the **horizontal nor vertical coordination** in place. In Nouvelle-Aquitaine, as France in general, intersectoral coordination is usually well developed and efficient, although it is not the case from a multilevel perspective. The case study of the Dresden Region showed the formally well-established coordination between the federal state, regional and local level as well as between spatial planning and sectoral planning instruments. However, with regard to practice and the implementation of preventive measures there is still potential for improvement.

The **collaboration and cooperation** between different departments in terms of DRM and CCA are a common challenge still unsolved. Specific departments (agriculture, environment, climate change, infrastructure, planning, etc.) may be totally or partially responsible for the preparation of a DRM and CCA plan (in some cases, in regard to a specific hazard). Besides the plan, necessary resources that support the formulation of such plans (as mapping, resources allocation, risk and vulnerability analysis, etc.) also do not have a sufficient integration and common elaboration and use among departments.

DRM are implemented at regional level in most of the case studies, usually by sectoral departments, and its planning, assessment and evaluation are very dependent on which natural hazard is to be managed. Again, a proper effective integration of DRM with spatial planning is missing in most of the cases. The identification of hazard-prone and risk areas is part of that (in some cases created at local level and compiled from them), and resulting maps are usually available not only for transversal use within the administration, but also provided in open access portals. Theoretically, spatial planning sets the scene and contributes to a DRM general framework (phase of risk prevention), while land-use planning at the local level establishes building restrictions based on those hazard-prone areas (and in some cases hazard-source areas, see Dresden Region case study).

In the case of flood risks, the implementation of the national legal planning framework is in all cases in line with the Flood Risk Management Directive (FRMD, 2007/60/EC). In some case studies other documents are also reference, such as the renowned Water Act and the Delta Act in the Netherlands. Regional and local levels give support and contribute to the elaboration of sectoral plans, but hardly have executive power to take decisions (except at local level) in terms of DRM. Considering the macro-regional analysis included as an ESPON-TITAN case study of the Alpine Region, the findings showed that there is no centred management system or common approach to be followed, because many hazard types do not need a harmonised and central management approach. Cross-border cooperation may however help to learn from each other or join forces to fight disasters and manage natural hazards.

In regard to the elaboration of the information to be used as a basis for DRM, the consideration of climate change differs considerably among the studied cases. **CCA measures**, and the consideration of future scenarios for mapping risk and vulnerability are issues that are in general considered by the case studies, although its effective integration to spatial planning is not always a reality. However, in local plans adaptation and mitigation measures were considered in some cases (e.g.: Pori City, given its proximity to the sea and river affected by historical floods). In general terms, action plans for the adaptation to climate change takes place at both national and regional levels, with some approaches also at local levels (revealed by the city-level case studies Pori and Rotterdam). However, some of ESPON-TITAN case studies well represent the successful integration of CCA instruments, such as the Lombardy region, Rotterdam (considering the Delta Act applied at national level) and partially, Nouvelle-Aquitaine.

Emergency management is, in all case studies, held by **Civil Protection** departments, established at the national (or federal state) level, which competences descend in a coordinated way to lower administrative levels, according to the type of disaster to be managed. Depending on the range of the disaster, the administrative levels involve and coordinate other authorities with relevant competence, such as water basin authorities, environmental departments or fire departments. A formal communication sequence is established in clear protocols to be followed by all-level administrations, starting from the local, where the disaster has started, up to the following levels, according to the magnitude and extension of the effects. In

levels and departments, to face disasters at regional level. Thus, formal measures are not by itself a guarantee for successful DRM, since it has to be built on a basis of trust, information exchange, harmonisation of concepts, data sharing, etc. Awareness raising and communication with the community in the case of a disaster, are in majority managed by local and regional authorities, usually based on social media channels.

In relation to impacts and policies, in the cases of Prague and Rotterdam, there are evidences that their **economic impacts have been reduced as far as introduction of preventive and adaptive measures started** (for Prague, see details economic impact analysis and conclusions in Chapter 4 and Annex 2). Impacts are undoubtedly higher in areas where preventive actions are absent, and there resides the importance of having DRM and CCA measures integrated to spatial planning. In summary, ESPON-TITAN case studies that outstands on that are Prague, Dresden and Rotterdam, in respect to flood protection, Po river basin. Specific lessons learned and more detailed analysis on cases studies are presented on Annex 5 and individual case studies report.

8 ESPON-TITAN Main policy messages and recommendations

The ESPON-TITAN policy recommendations (PR) cover six topics described in Table 8.1, which address different parts or stages of the policy process, namely problem identification and agenda setting, formulation and adoption, implementation, and evaluation (based on e.g.: Howlett and Ramesh, 1995; Jordan, 2001; Burke, 2020). Moreover, the suggested policy recommendation topics also cover methodological issues, that receive a deeper consideration on the recommendations for future research (Chapter 9). The policy recommendations mostly concern action at the EU level, although since ESPON stakeholders include the national, regional and even local policy makers, a specific set of policy recommendations dedicated to those levels was added (Chapter 10), as an extraction from the case studies (Chapter 7).

Table 8.1 Contextualization of ESPON-TITAN Policy Recommendation

Economic impacts	(A) How to improve methodologies for calculating the economic costs of disasters and natural hazards and assessing their impact at different territorial scales.
	(B) What could be done to improve data availability on economic losses associated with disasters and natural hazards, especially at local and regional levels.
Connection between economic losses and appropriate DRM and CCA measures	(C) How to link measurement of economic losses due to disasters and natural hazards with the development of appropriate disaster risk management and climate change adaptation measures at different territorial scales.
Improvement of DRM and CCA practices	(D) To what extent different funding mechanisms (European Structural and Investment Funds, Financial Instruments, etc.) can be better mobilised to further support disaster risk management and climate change adaptation at territorial level.
	(E) How should regions, cities and local governments cooperate to ensure the efficiency and coordination of various measures related to disaster risk management and climate change adaptation? What could be a role for different umbrella organizations?
	(F) How to better integrate DRM and CCA into legislative frameworks and instruments of territorial development?

Chapter 8 offers a summary of the most relevant policy recommendations per topic A to F (Table 8.1), the most relevant were selected. Selection criteria to identify them were the potential role the EU and its institutions can play in formulating specific actions, e.g. by initiating policies, directives, data bases etc. The extended policy recommendations are documented in Annex 6.

In order to give this quite heterogeneous set of requested policy recommendations a comprehensible structure we correlated the policy recommendations with the stages of the policy process. Table 8.2 provides an overview of ESPON-TITAN policy recommendations. The ones highlighted in orange are the relevant ones that are described in the present report; the rest others are developed in Annex 6. The recommendations highlighted in green refer to methodological recommendations, which are presented in Chapter 9 of this report. As already stated, the policy recommendations are structured around the different stages of the policy process, and the description specifies to which of them the policy recommendation could contribute (problem identification and agenda setting; formulation and adoption; implementation; evaluation).

Table 8.2 Overview of policy recommendations in each group (in orange, policy recommendations described in this chapter; in green, policy recommendations described in Chapter 9)

(A) Methodologies for calculating economic costs and impacts of disasters and natural hazards	A-1: Harmonisation of concepts and methods for risk assessment and risk evaluation
	A-2: Further development of appropriate damage functions for different types of hazards including the calculation of uncertainty parameters
	A-3: Research on indirect losses and impacts should increase
	A-4: Support methodological innovations in risk assessments regarding the spatial and temporal dimension of risk
	A-5: Conceptualisation of criticality as a basis for contributing to the evaluation of risk
	A-6: Support regions and the local level in using research and cooperation projects more strategically for DRM and CCA
	A-7: Research on how to consider human losses as additional impact of natural hazards, on their inclusion in decision-making processes
(B) Improve data availability on economic losses from disasters and natural hazards at local and regional levels	B-1: Development of a framework for the collection of the necessary data at the local level across Member States/authorities
	B-2: Disaster-related damage data and reporting should be more granular, including the distinction between direct and indirect damages to avoid double counting in economic modelling
(C) Link measurement of economic losses with the development of DRM and CCA measures	C-1: DRM and CCA measures and plans should always account for the total economic impacts of the occurring natural hazards, including both direct and indirect losses as well as risk aversion factors
	C-2: Support a paradigm shift towards a spatially oriented risk assessment and management by including the spatial (cross-sectoral, multi-risk perspective) and temporal (risk dynamics, emerging risks) dimension of risk
	C-3: Conceptualisation of criticality and consideration of critical infrastructures (CI) in the evaluation of risk (systemic risk/criticality perspective)
(D) Mobilise European funding mechanisms to further support DRM and CCA at territorial levels	D-1: Focused promotion of a pro-active and prevention-oriented design of EU funding instruments in combination with quality objectives regarding funding of reconstruction
(E) Cooperation and coordination of regions, cities and local governments	E-1: Develop cooperation structures between regions, cities and local governments but also between different experts based on a balanced set of formal and informal elements
	E-2: Establish a clear coordination structure for DRM and provide it with leadership qualities
(F) Integration of DRM and CCA into legislative frameworks and territorial development	F-1: Support DRM and CCA issues during amendment processes of EU Directives
	F-2: Mainstreaming climate change adaption in territorial development policies

In the following sections, the key policy recommendations highlighted in the Table 8.2 above are presented individually. **The first block of policy recommendations relates to economic impacts (focused on methods and data)** (sections 8.1. and 8.2), where a general question permanently emerges: the trade-off between high resolution and local/regional accuracy of data on the one hand and, on the other hand, the comparability and homogeneity across all regions and statistical units across the ESPON space. Although there is not an easy-to-achieve solution, this issue is addressed by suggesting standards for the collection of comparable data and transparency in methodological approaches.

The second block presents a policy recommendation related to the connection between economic losses and appropriate DRM and CCA measures (section 8.3). As a central issue for linking them, a paradigm shift towards a more systemic and holistic view on impacts and the evaluation of risk seems to be indispensable. The inclusion not only of direct but also indirect losses describes this overall principle which is described in the policy recommendation below. More information regarding the interconnected issues of the spatial (cross-sectoral, multi-risk perspective) and temporal (risk dynamics, emerging risks) dimension of risk, as well as criticality as an additional issue to evaluate risk is included in Annex 6.

The third and last block covers the policy recommendations related to the improvement of DRM and CCA practices in terms of funding, cooperation and legislation (sections 8.3, 8.4 and 8.5). There are several options how they can be improved from an EU and Member State perspective. Funding, cooperation, and legislative approaches are differentiated here. In addition to the original two topics that were mentioned here, a third one was added regarding the instruments and policies.

8.1 Harmonisation of concepts and methods for risk assessment and risk evaluation (A-1)

This policy recommendation contributes to answering the question how to improve methodologies for calculating the economic costs of natural hazards and assessing their impact at different territorial scales. The policy recommendation builds on the remarkable efforts that have been made especially by JRC in recent years, which established the Risk Data Hub that provides and further develops the presentation of comparable spatially differentiated data on disaster risk (Antofie et al., 2019; 2020).

The findings from ESPON-TITAN showed that a harmonisation of methods and data are seen to be difficult because each country has its own hazard and risk profile and designs an own approach and logic behind, according to own hazard profile or needs or the national system and legislation (often result of a historic development), thus all countries have their own DRM and CCA methods which makes a comparison of assessment results difficult. Also, interviews with experts showed that at least from a regional or local perspective a harmonisation of data, methods and concepts is questioned (see Chapters 6 and 7).

However, any kind of opposition against harmonisation approaches for methods should only be understood against the background of political or resource-related reasons (unwillingness to change long-established methods and procedures, lack of financial or personnel resources to implement new methods). In fact, methodological harmonisation is possible and necessary whenever reliable cross-regional and/or cross-national comparisons/evaluations are required (PR F-2), although they do not question the necessity of context-specific risk evaluations as normative judgements and basis for risk management actions.

This is also supported by the recent report on NRAs
that across Europe, risk assessment has to be done in a way to make risks comparable, as the comparability of evidence is the key issue in evidence-based policy making. It is vital to obtain harmonised information to create a more accurate picture of the gaps and needs at EU level:
allow the comparison of risks across hazards, regions, time, assets or sectors. These would allow aggregation of risks arising from the same hazard and understanding of relative importance of different risks for prioritization of DRM actions. It would establish a common understanding of risks that country is facing when consulting among each other. It would pave the way to the multi-hazard risk assessment, introducing interactions and cascading effects in modelling, as well as provide some analytical interpretations of

realistically, harmonisation of the risk assessment process shall remain at the level of terminology, data, risk concept, standardized steps of risk assessment process and presentation of the results
al., 2021:14).

Such kind of harmonisation should happen in three steps; each step would mean a higher degree of harmonisation: (1) agreement on the conceptual frame (e.g. risk-based approach or inclusion of residual risk or the inclusion of systemic criticality), (2) agreement on criteria (data quality, complexity, indicators) to guarantee the quality of the assessment/evaluation method, (3) agreement on a specific assessment method. An example how the integration of approaches and data across different territorial levels was implemented, is the Climate impact atlas in the Netherlands. Although it is a national (and not European-wide) approach, it shows how various knowledge institutes and consultancies are involved and contribute with source materials (Van der Vlugt, 2020).

As a specific action, aligned with Pol announce a proposal for a regulation of a harmonisation of concepts and methods for risk assessment and risk evaluation in order to achieve comparable and comprehensive risk assessment and evaluation standards to support DRM policies at European level, e.g. for the further development of the EU Solidarity Fund or for defining funding criteria for supporting infrastructure investments in the Regions and Member States. This should be based on an earlier communica

JRC-supported Risk Data Hub under the DRMKC. The JRC efforts in this regard should be further extended (several hazards are not yet covered) and the methodology of the approach, the used sources and the constraints could be described more transparently. Further, the accessibility of this information should be improved, which supervision could be assumed by the EC (including JRC) through, for example, DG-ECHO. Indirectly, also the Regions and Member States could contribute to the harmonisation process by applying the assessment and evaluation criteria, and providing proper data. Thus, this policy recommendation contributes to the stage of formulation and adoption within the policy process.

8.2 Development of a framework for the collection of the necessary data at the local level across Member States/authorities (B-1)

This policy recommendation contributes to answering the question what could be done to improve data availability on economic losses associated with disasters and natural hazards, especially at local and regional levels across Member States/authorities. In contrast to the previous policy recommendation this one aims at the collection of the necessary data at the local level across Member States/authorities in order increase the comparability of results and thus complements policy recommendation A-1. This includes standardised data collection at the local scale in terms of disasters and natural hazards, allowing the consideration of implicit local knowledge. While damage data describe the strength and patterns of impacts of disasters, the data on exposure and vulnerability describe the reason for the impacts. The importance of gathering these data resides in the fact that they are risk components, based on which management measures could be implemented. (Antofie, 2020). The Risk Data Hub developed by JRC aims to support the effectiveness and efficiency of DRM by providing access to, and sharing of EU-wide curated risk data (Antofie et al., 2019; 2020), including specific data on losses (Faiella et al., 2020).

The databases (the Risk Data Hub, Windstorm Information Service -WISC- and EM-DAT) used in the ESPON-TITAN project for their information on economic damages per event exhibited several differences in how they collect and harmonise data (see Annex 1 and 2, with special reference to the local economic analysis performed in Prague and Charente-Maritimes). The assessment of the economic risk would benefit from more detailed damage information. Small differences in the location of capital stock (location of buildings in our outside flooded areas) can have tremendous effects on the actual damage caused by a hazard. The collection of the same type of data in all ESPON countries would significantly reduce the data gaps identified in our study. Some of the main differences identified during our research are: (1) the reported time of occurrence and the spatial extent of a disaster; (2) the classification of the type of a disaster and the definitions of their indicators; (3) currencies and prices of economic losses.

This is also strongly recommended by in the NRAs report on DRM. Although the Risk Data Hub of JRC covers a large range of hazards, loss and risk data comparability is still an open issue in order to make the information useful for disaster risk assessment. Thus, harmonisation (or even, standardisation) of loss data gathering is needed (collection of disaggregated data in loss and damage databases), and helps to empirically identify the physical vulnerabilities of assets under different hazards

Data collection should include local authorities because they can play a very important role in this as they are in place to know better than anyone else the local context. A better use of local and tacit knowledge could thus help to close knowledge gap and make available data more useable and actionable at the local level. However, giving this responsibility to the local authorities will lead to unharmonized collected data and may lead to less granular data (see policy recommendation B-2). To address this limitation, and taking into account what was suggested above, authorities at higher levels (e.g. ESPON) could develop a framework for the collection of the necessary data in order to harmonise the collection across Member States/authorities, which can then be used by the local authorities for the measurement and data collection.

As a specific action we recommend that the EC discusses and evaluates different approaches for developing such a framework. On the one hand, and in connection with policy recommendation A-1, the existing JRC-Risk Data Hub could act as a motivation engine for Regions and Member States contribution with comparable data. On the other hand, EUROSTAT could extend their data entry forms, regarding the collection of hazard, risk and damage data, towards the LAU level. Also, the INSPIRE Directive could be the EC should further foster cooperation with insurance and re-insurance companies. Thus, this policy recommendation contributes to the stage of implementation within the policy process.

8.3 DRM and CCA measures and plans should always account for the total economic impacts of the occurring natural hazards, including both direct and indirect losses as well as risk aversion factors (C-1)

This policy recommendation contributes to answering the question how to link the measurement of economic losses due to disasters and natural hazards with the development of appropriate DRM and climate change adaptation measures at different territorial scales.

The selection of a defence measure against a hazard should be made on the basis of the comparison of the cost to implement this measure, against the damage cost avoided by the prevention of the disaster. Therefore, a holistic investigation of both types of costs occurred by a disaster, and a projection of the potential costs of reoccurrence of the disaster in the area in different intensities, is key. In the ESPON-TITAN project the case study of Prague (local methodology, see Chapter 4 and 7) showed the importance of damage functions to predict the damages in certain areas. By using different scenarios presenting different flood intensities, the Cost-Benefit Analysis (CBA) showed the avoided cost per scenario and clearly stated the benefit of flood prevention measures. As such, CBA can be an important tool to show how DRM and CCA practices can be formulated as structural development making such measures applicable for funding. However, if not only direct but also indirect losses shall be taken into account and if this is the basis for designing DRM measures and CCA plans, these have to be addressed in supra-regional, national or even supra-national plans because of the cross-border character economic networks, which could be affected by disruptions of infrastructure networks and supply chains. CBA also can be applied in the systemic criticality context: the higher the protection worthiness of CI is in order to avoid economic impacts on the EU Single Market, the more expensive DRM and CCA measures could be (security, cohesion, functioning of Single Market as criteria/objectives) (see section 9.1.5). In order to further improve the quality of CBA there is also a need to include those damages in the assessment that are normally neglected due to risk aversion in case of low probability/high damage events. Aversion factors (can be factor 4 in case of 1.000-year annuity) can be used to improve the estimation of indirect losses. Any kind of under-estimation of risk and thus of potential losses leads to an increase of the protection gap between insured losses and the losses that finally occur following an event (Antofie, 2020).

The consideration of indirect losses is already partly done by DG ECHO and some studies (e.g. in the PESETA project; for climate change see Szewczyk et al., 2020), but it still needs a broader understanding and stronger coordination is still needed. As a specific action we recommend that the Commission launches a consultation process on collecting the point of view of institutions, businesses, associations, local authorities etc. to provide their point of view regarding options for a more systemic and holistic view on damage and risk assessment and evaluation. This can be initiated by a Green Paper that discusses the options of implementing this paradigm shift in policies, e.g. as a part of the implementation process of the amended EIA Directive, the future amendment of the SEA Directive or the creation of a European Norm for cost-benefit analyses including indirect and systemic costs and benefits. Thus, this policy recommendation contributes to the stage of problem identification and agenda setting within the policy process.

8.4 Focused promotion of a pro-active and prevention-oriented design of EU funding instruments in combination with quality objectives regarding funding of reconstruction (D-1)

This policy recommendation contributes to answering the question to what extent different funding mechanisms (European Structural and Investment Funds, Financial Instruments, etc.) can be better mobilised to further support disaster risk management and climate change adaptation at territorial level.

The ESPON-TITAN findings have shown that there are several funding instruments for supporting DRM and CCA are available. Although some funding instruments aim at the prevention of disasters as well as at climate change adaptation there is still potential to focus more on pro-active and prevention-oriented measures. The efficiency of measures could be increased by providing funding only under the condition that certain quality criteria are fulfilled regarding, e.g. reconstruction measures (Chapter 6).

As specific actions we recommend to further develop instruments that can potentially support DRM and CCA. The Civil Protection Mechanism (CPM), the EU Solidarity Fund (EUSF) or the European Structural and Investment Funds (ESI Funds) complement each other well. However, in the event of a disaster, a country must activate different instruments/funds to deal with the consequences. It is therefore advisable to make the solidarity fund more proactive or to ensure that the funds are easily linked. This would complement recent trends that can be observed in the NRAs, which show that with growing importance, a long-term prevention-oriented planning perspective complements the short-
2021).

Funding should an also be linked to CCA action plans, on which DG CLIMA and DG ECHO should work more closely together in the future. The new EU Strategy on Adaptation to Climate Change (EC, 2021) especially understands the financial system as an important element to increase resilience to climate and environmental risks (especially risks and damage arising from natural catastrophes).

Gaps exist for promoting CCA and DRM through the LEADER programme. There are options to recommend linking the instrument with CCA and DRM. Moreover, adaptation action, especially at the regional and local levels, requires appropriate funding, and this is why EU structural funds should be granted only under the precondition of an existing (local) adaptation strategy. In this respect the recently adopted EU Strategy on Adaptation to Climate Change (EC, 2021) makes a large step forward as the EC will enhance climate proofing guidance, develop an EU-wide climate risk assessment, increase cooperation with standardisation organisations to climate-proof standards and to develop new ones for climate adaptation solutions and support the integration of climate resilience considerations into the criteria applicable to construction and renovation of buildings and critical infrastructure. These considerations, however, should not be restricted to Climate Change Adaptation, but should also incorporate aspects of DRM. For example, funds for reconstruction (especially the EUSF) should be connected to certain conditions/requirements (thresholds, appropriate assessment methodologies, e.g.: inclusion of indirect costs, data provision) in order to guarantee a reconstruction that is better adapted to future hazards and changes.

Thus, this policy recommendation contributes to the stage of implementation within the policy process. Such an approach needs a harmonised/comparable assessment methodology for all countries (see PR A-1 and B-1) in combination with a monitoring mechanism. . It should be evaluated (with clear funding criteria), if certain investments (e.g. for maintenance), that indirectly contribute to disaster prevention, can be re-labelled in this context in order to be eligible for being funded under CPM and/or EUSF. This, of course needs clear funding criteria in order to avoid that regular infrastructure maintenance to be re-labelled as disaster risk reduction, which would be an abuse of earmarked funding.

8.5 Develop cooperation structures between regions, cities and local governments but also between different experts based on a balanced set of formal and informal elements (E-1)

This policy recommendation contributes to answering to the following set of questions:

- How should measures related to disaster risk management and climate change adaptation be coordinated between regions, cities and local governments to ensure their effectiveness?
- How should regions, cities or local governments cooperate with other regions, cities or local governments in order to increase the efficiency of DRM and CCA measures?
- What could be a role for different umbrella organisations?

This topic was re-formulated in order to differentiate more specifically between the terms: coordination/cooperation and efficiency/effectivity. This section relates mainly to the findings from Chapters 6 and 7 (all case studies, plus Alpine case study, as umbrella organisation), although it also includes findings and recommendations made by other institutions for enhancing the coherence between DRR and CCA in policy and practice (EEA, 2017).

The case study analyses in the ESPON-TITAN project showed that long-lasting, sustainable and effective cooperation has to be built on formal agreements but can only be filled with life in an atmosphere of personal connections, mutual trust as well as open-mindedness to share experiences and learn from others (case egger, 2020; Heil, 2020; and Dresden Region: Müller, 2020; Korndörfer, 2020; Rümpel, 2020). As main benefits of cooperations and successful contribution to DRM the interviewees highlighted the possibility to learn from each other, exchange ideas and experiences, learn what can be possible. However, the success of (transnational) cooperation depends very much on the delegates who represent the different national (regional) authorities: are they enthusiastic, practical enough and able to connect with others, do they have the skills and power to support and implement the agreements/initiatives back home?

As specific action we recommend that in the field of DRM and CCA, formal EU/Community funding of transnational cooperation (INTERREG Programme) or cooperation among the Member States themselves, should be further supported. Especially the joint work on specific projects where results and data have to be shared on a regular basis help to foster cooperation structures (Antofie, 2020). However, the findings further suggest to organise cooperation-oriented expert groups that are characterised by a continuity of topics and personnel in order to build knowledge and trust between group members and at the same time have the opportunity to work independently from funding guidelines and reporting requirements. Such expert groups could be installed for a certain trans-national or trans-regional area that is characterised by a specific hazard or risk profile. Experts from public authorities and different territorial levels could cooperate for a medium-term period (e.g. in accordance with the 7-year EU funding periods) in order to establish long-term cooperation structures that last even beyond the funding period.

A formal element for a successful cooperation is to provide the cooperation with a political mandate which shows commitment and guarantees resources to organise the cooperation process. In a cooperation contract, specific agreement can be fixed, e.g. regarding data provision and exchange which is especially important in any cross-border cooperation. Finally, a long-term funding definitely contributes to establishing and maintaining cooperation.

However, formal elements have to be supplemented by informal elements such as the personal exchange on working levels, establishing personal contacts and trust (have contact details at hand, learn key phrases in other language in order to communicate more easily in case of an emergency). Another important cooperation element is to bring groups together that have different responsibilities/that have different

prevention oriented (water authorities, spatial planners) actors, so both can learn different perspectives, understand ea

Thus, this policy recommendation contributes to the stage of implementation within the policy process.

8.6 Support DRM and CCA issues during amendment processes of EU directives (F-1)

This policy recommendation contributes to answering the question how to better integrate DRM and CCA into legislative frameworks and instruments of territorial development.

Case study interviews in the ESPON-TITAN project confirmed that EU directives (especially WFD and FRMD) can have a significant impact on establishing and implementing certain and especially new issues at all administrative levels. Their implementation helps to support arguments in controversial discussions about the necessity of certain DRM or CCA related actions (case study interview Dresden Region: Korndörfer, 2020).

The Floods Directive 2007/60/EC (EC, 2007b) clearly addresses disaster risk management, however, climate change adaptation has not been addressed so far. Nevertheless, from the second cycle of implementation of the Floods Directive onwards (2016 2021), it is mandatory to include the likely impact of climate change in the Preliminary Flood Risk Assessments. For the flood hazard and risk maps, no explicit reference to climate change is made; however, a summary text on the methods used to include climate change in the flood scenarios can be reported as optional information (EEA, 2016).

The recent amendment of the *Environmental Impact Assessment Directive (2014/52/EU)*
change will continue to cause damage to the environment and compromise economic development. In this regard, it is appropriate to assess the impact of projects on climate (for example greenhouse gas emissions) and their vulnerability to c
(of both climate and society) has to be considered when assessing the effects of a project on the environment (EEA, 2013).

A similar reference is missing in the Strategic Environmental Directive (EC, 2001), although the DG Environment argues for an inclusion of climate change (EC DG Environment, 2013). An amendment of the SEA directive that considers the local impact of climate change more explicitly when assessing the effects of a plan or program on the environment appears to be urgently needed. In providing such an amendment, land-use policies could be supported that are made in accordance with a given climate change impact profile.

As specific action we recommend is that the Commission, and especially the Directorate Generals, check and revise the potentials to support DRM and CCA and consider these during amendment processes of EU Directives. Some attention to DRM and CCA has already been paid in those framework directives which have a territorial dimension. In some cases, DRM and CCA issues were not included from the beginning, but introduced in later amendments of the Directives.

It is clear that the issue of DRM should not be split into several legislations, and of course this complex issue needs an integrated approach (such as provided in EU guidelines for DRM). Thus, it would be good to assess the relevant EU Directives so that they are in line with the EU guidelines for DRM, as long as it is in support of the DRM guidelines. The aim is to have a more integrated approach, but not to make it more complex. Nevertheless, we see the potential that in future amendments of relevant EU Directives specific issues can be tackled that support what could be described good DRM or CCA practice (including support of the DRM guidelines). Examples of such amendments in the past are the amendments of the SEVESO III Directive 2012/18/EU (EU, 2012).

CCA and DRM should thus be integrated in the aforementioned framework directives on water, floods and habitats in order to optimise the fit between the scope of the problem and the scope of decision making. For example, extreme floods are one of the biggest (climate change adaptation) challenges and likely to be the cost drivers for adapting infrastructures. However, both efficiency and effectiveness of fluvial flood risk management depend on a transnationally coordinated river basin management approach in order to avoid passing on negative consequences further downstream (EEA 2016).

Thus, this policy recommendation contributes to the stage of implementation within the policy process.

9 Recommendations for future research

The following research recommendations were developed in parallel to the policy recommendations (see Chapter 8 and Table 8.1). As they cover methodological issues, they are discussed in this section on future research needs.

Most of the presented recommendations are related to methodologies and based on the research performed in ESPON-TITAN, that includes some shortcomings and challenges that need to be addressed (Sections 9.1, 9.2, 9.3, 9.4 and 9.5). Apart from the ESPON-TITAN own findings, there are also research efforts from other institutions addressing CCA, DRM, or both.

Although not explicitly focused on future research, a last recommendation (Section 9.6) was included in order to strengthen efforts of actors on the different territorial levels to strategically use research funding as a tool to support DRM and CCA practice.

9.1 Further development of appropriate damage functions for different types of hazards including the calculation of uncertainty parameters (A-2)

Findings from ESPON-TITAN: Currently, there are no widely available damage functions for other hazards than river floods and, to a certain extent, earthquakes. Even though the damage function for flood is well developed and covers all the European countries, there is still room for improvement (Chapter 3).

Description of recommendation for future research: The improvement of damage functions for floods is mostly related to data input (to make it as event specific as possible) and to better illustrate the uncertainties of these damage functions. For instance, the damage functions used in the ESPON-TITAN study apply to all the countries in Europe. This leads to uncertainty and inconsistency of results, as the damage functions in practice differ per country. Moreover, the damage functions are developed for urban environments as the underlying data on maximum damages is derived from construction cost surveys, which mainly concern costs of urban types of buildings (Huizinga et al., 2017). For the maximum damage value, it is also important to note there is a difference between urban and rural house prices. In general, house prices are more expensive in urban areas assuming houses are the same size (Huizinga et al., 2017). The uncertainties mentioned above are not exhaustive as many other uncertainties derive from using global damage functions. As such, there is a need to collect more country and regional data to improve the data applied in the damage functions. For future reference, uncertainty parameters should be calculated to show the level of uncertainty when using damage functions.

For hazards apart from river floods, ESPON-TITAN used a more bottom-up approach to distribute the damages among sectors for each event. However, this approach was only possible as there were not many events recorded for these hazards. To improve the methodologies that distribute economic damages among sectors, there is need for further research into damage functions for earthquakes, droughts, and windstorms.

Target of recommendation for future research: EU level (JRC might develop damage functions with national resolution) and national level research funding institutions for providing support for research teams, however, it can be assumed that the development of damage functions most likely is a task for academia/individual research teams.

9.2 Research on indirect losses and impacts should increase (A-3)

Findings from ESPON-TITAN: The Impact Pathways revealed a wide variety of indirect impacts of the four natural hazards, which due to methodological and budget constraints were not quantified in our approach (Chapter 3).

Description of recommendation for future research: Our research showed that the indirect losses can be as high as the direct losses, and this refers only to a very narrow range of types of indirect impacts. Given that different natural hazards give rise to different indirect impacts, there are ample opportunities to explore indirect losses and thus increase the accuracy of the estimation of total economic losses of disasters and natural hazards. Methodologically it should be discussed if indirect losses due to economic triggering (supply chains) shall be distinguished from indirect losses due to economic impacts because of triggering of natural hazards (or even NATECH hazards) there might be an added value, however it seems difficult to disentangle the effects.

Target of recommendation for future research: EU level and national level research funding institutions, individual research teams.

9.3 Support methodological innovations in risk assessments regarding the spatial and temporal dimension of risk (A-4)

Findings from ESPON-TITAN: Project findings indicate that real integrated multi-risk assessment methodologies as well as dynamic changes in risk settings are still hardly developed. Even recent and advanced studies, that explicitly develop a multi-hazard approach, including the temporal change in hazard patterns and the impacts on critical infrastructures, still have to accept limiting assumptions: independent hazards (without accounting explicitly for hazard interrelations), no estimation of probabilities of coincidental or cascading events and static vulnerability (Forzieri et al, 2015: 37; 126; 2016; 2018). Although challenging, dynamic changes and interactions should sooner or later be integrated into risk assessment approaches.

Description of recommendation for future research: Spatial planning must adopt a multi-hazard approach in order to appropriately deal with risks and hazards in a spatial context, which is inherent whenever natural hazards are addressed. With a multi-hazard perspective, cross-sectoral as well as triggering events come into focus. Some European regions, such as Lombardy based on previous disaster experiences, have already established hazard assessments that cover several natural hazards in a multi-scale approach (Lombardy Region: May, 2020). Further, countries, regions and cities are not static but in a permanent change if not transformation, and scenario-based approaches that consider uncertainties are needed for risk assessment. Thus, methodological innovations are needed in order to consider the spatial and temporal dimensions of risk.

Target of recommendation for future research: EU level and national level research funding institutions, individual research teams.

9.4 Conceptualisation of criticality as a basis for contributing to the evaluation of risk (A-5)

Findings from ESPON-TITAN: Critical infrastructures can amplify risks within the system (e.g. the whole country) although the physical damage can be restricted to only a very limited area (e.g. highly frequented bridge) or vice versa: physical damages in remote areas can have considerable negative (economic) effects on the own region or town.

Since the adoption of the Council Directive 2008/114/EC, the EU provides a framework for identifying critical infrastructures at national and EU levels. The topic of critical infrastructure disruptions is also addressed in detail with regard to concepts, availability of data and assessment and management approaches in the report

et al., 2021). Also, the report "Science for Disaster Risk Management 2020" acknowledges the important role that the research on critical infrastructures plays for improving DRM. The report describes and discusses criticality and cascading effects due to infrastructure failures and also points on management priorities how to protect critical infrastructures and how to deal with consequences of such failures (see also OECD, 2019). However, the report further calls for a comprehensive risk assessment that should combine the multiple regulations and activities regarding critical infrastructures (Casajus Valles et al., 2021). Such risk assessment that includes the criticality of infrastructures would embrace a combined contingency and systems approach, which could help "to identify hazards, vulnerabilities and threats, update the list of critical infrastructures and essential services, determine interdependencies and ultimately define capability targets" (Casajus Valles et al., 2021). This demand, together with the own findings shows that methodologies for criticality assessments of infrastructures are still at the beginning. Development, validation and usability for implementation of policies for infrastructure development and preventive DRM shall be further supported.

Description of recommendation for future research: To further operationalise the spatial dimension of systemic criticality, a normative judgement is required to determine the worthiness of protection of specific

judgement should ideally

consider the result of a sectoral criticality assessment, which could in principle be performed on various spatial levels depending on the extent of the respective infrastructure system (good practice example: federal spatial plan for a nationwide spatial flood protection (Bundesraumordnungsplan Hochwasserschutz [BRPH]) (BMI and BBSR, 2020). Thus, multi-risk assessment is not just a multi-hazard assessment, but requires a consideration of cascading effects even outside the exposed area (Figure 9.1).

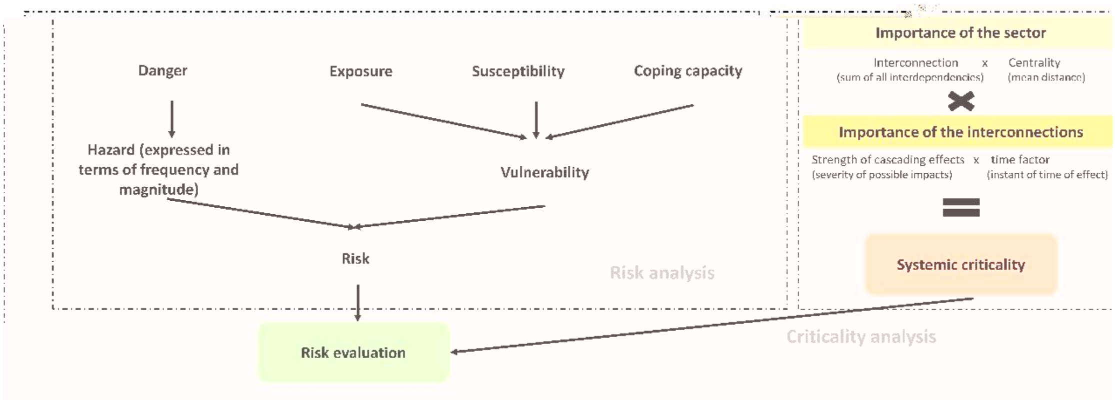

Figure 9.1 Criticality analysis as part of the risk evaluation framework
[Source: Greiving et al., 2021]

Target of recommendation for future research: EU (DG MOVE, DG ENER but also DG REGIO in regard to cohesion policy), EC, EU level and national level research funding institutions, individual research teams.

9.5 Support regions and the local level in using research and cooperation projects more strategically for DRM and CCA (A-6)

Findings from ESPON-TITAN: In the ESPON-TITAN case study analyses some observations were made regarding the function that research and cooperation projects can have for introducing new topics, testing new methods and binding stakeholders to certain DRM and CCA related topics and objectives. However, the application process is full of prerequisites and implementation often sputters after the project funding period (case study interviews Dresden Region: Seifert, 2020; Müller, 2020; Korndörfer, 2020).

Description of recommendation for future research: The European Territorial Cooperation (ETC), also known as *Interreg*, is an obviously relevant funding scheme. It provides a framework for joint action between Member States and promotes trans-boundary cooperation. The relevance of territorial cooperation for adaptation is evident due to the cross-border character of many impacts of climate change and is therefore a joint responsibility, which calls for strong coordination and cooperation. Climate change-related actions

focus on those regions in Europe that were identified as being particularly vulnerable (such as South-eastern Europe or mountain regions). Also, research projects under the *Horizon 2020* programme or under national research programmes have shown that they can raise attention and activate regional and local stakeholders and the public. However, after the end of the project, further activities are often not continued.

Nevertheless, regions and local authorities can use research and/or cooperation projects strategically for DRM and CCA as they fulfil different functions: (1) commit policy makers/decision makers/planners to certain topics that were only in the background before; (2) acquire additional financial/personnel resources and thus be able to tackle challenges in a way that was not possible before; (3) bind personnel/project group across departments/sectors, support intra-communal communication.

Thus, it is also recommended to provide especially research projects with follow-up implementation phase (better: permanent positions that further support DRM and/or CCA) in order to transfer the results/findings into practice.

Target of recommendation for future research: EC (DG REGIO, DG RTD), Member States, regional and local authorities.

9.6 Research on how to consider human losses as additional impact of natural hazards, on their inclusion in decision-making processes (A-7)

Findings from ESPON-TITAN:
assessment methodologies (Chapter 4), making the focus exclusively on economic-related assessment. It is very likely that the inclusion of human losses in the assessment methodologies would have led to different distribution of economic impacts of natural hazards.

Description of recommendation for future research: Although this issue was not studied in depth, we are aware that the (potential) losses to human lives are often under-estimated because of ethical and methodological reasons, and that it is a challenge to be represented in economic terms. Given the interest shown on these terms, we recommend broadening research to consider human losses as additional impact of natural hazards, as well as to further discuss how this issue can be considered in decision-making processes.

Target of recommendation for future research: EU level and national level research funding institutions, individual research teams.

10 Lessons learnt from regional and local case studies

The policy recommendations generated from ESPON-TITAN scientific findings are focused mainly on EU specific actions, which set is centred on topics that cover the different stages of the policy process, as well as methodological issues. These same topics were covered on the analysis of the eight ESPON-TITAN case studies (Chapter 7), of which some lessons learnt were extracted, based on practical experiences of regional and local stakeholders, that were, in most of the cases, technicians, policy- and decision-makers.

The investigation of these case studies was based on going through an exhaustive analysis of, not only the natural hazards that mainly affect each region and their economic impacts, but mainly on the DRM and CCA instruments in place in terms of legal framework, assessment and management. Special attention was put into their integration of these practices into spatial and sectoral planning, including cooperation and coordination dynamics.

From the analysis, some lessons learnt were identified in relation to the good practices on integrating DRM and CCA into spatial planning. Given that the selected case studies are representative from different regions across Europe, those lessons learnt may constitute a good reference for other regional and local administration. The following conclusions and lessons learnt were reach from the case studies analysis:

Territories should focus more on risk prevention activities rather than response/reaction, as it has a

Prevention is based on this knowledge, applied to the determination of urban and buildable areas. **Municipal planning must consider risks much more than they do nowadays, because it is the key instrument which regulates land-use.** Authorities should pay special attention to areas where buildings have been installed without much consideration or outdated methods concerning risk management in the past, as seen on the City of Pori, Po river Basin or Nouvelle-Aquitaine. Possible solutions are gradual delocalization, insurance, or urban rehabilitation. In this line, it must be highlighted that the support of urban rehabilitation, - climate change impacts and its associated risks, redesigning cities and territories in this direction. Urban planning irregularities were revealed, and are associated with high costs. To protect people's lives and incur the lowest costs, the most effective alternative is to avoid the urbanization of high-risk areas, whose maintenance and future safety can only be ensured if responsibility for them lies with clearly identified officials.

A top-down approach is still predominantly followed, although **vertical coordination and cooperation are very important for DRM and CCA**. Some good examples are the common geographic information platform of the Po river Basin, the role of Civil Protection in Andalusia or the interactive and online tools for DRM enhancing cooperation between the different administrative levels and the inclusion of citizens in the Dresden Region. Concerning CCA, adaptation strategies and action plans developed at the national and regional level should be transferred to the local level through adaptation measures.

Intersectoral coordination should be improved in all areas of risk management, as well as in the management of adaptation to climate change. In this context, policies for risk management and CCA cannot remain sectoral, but should be integrated with spatial planning and development programs as seen with several paths on the Dresden Region, in Nouvelle-Aquitaine and in the Netherlands. In the future, cross-sectoral measures should be better integrated with, and promoted, as part of adaptation measures.

A good example of vertical coordination is Rotterdam, in which the national government produces and communicates knowledge, generates policy at this level, and exercises leadership over other governments; and at the local level the spatial planning is mostly developed. The examples from Rotterdam show the need/possibility of rethinking land-uses under areas where flooding is foreseen to suffer changes resulting from climate change.

A sound strategy for DRM and CCA should involve all the relevant actors of the territory, as seen on the Dresden Region, City of Pori, Rotterdam and Po river basin. This cooperation and collaboration benefits from their innovation capacity, as professionals, universities, and enterprises are constantly developing new solutions and new skills, as seen on the Dresden Region and Po river basin.

Natural phenomena do not care about administrative borders, so cooperation between regions must be put in place. This cooperation must exist between regions within a country, as seen on the Po river basin, but also between countries, as seen on the Alpine Region and the Dresden Region. Cross border cooperation is key for transnational spatial planning, DRM and CCA. In this line, the Alpine Region showed the importance of transnational programmes, such as EUSALP, and transnational projects like GreenRisk4Alps.

The supranational level should set common standards for DRM and CCA strategies within the European Union. The success of the Flood Risk Management Directive 2007/60/EC is a good example of what can be done in the European institutions.

The case studies analysed showed that **in the long-term, sustainable and effective cooperation must be built on formal agreements, but it can only be filled with the human component**. Thus, personal connections, mutual trust and open-mindedness to share experiences and learn from each other is a key factor. In this line, the URBACT and INTERACT programs are good examples of how the European Union can foster this kind of exchanges. By keeping clear subsidiarity and proportionality principles, European dimension is necessary as a common house of benchmarking to help driving common improvements in these fields; by learning from the best practices, but also with decided leadership from Directives for First Pillar Policies and those in which territorial cross-border cooperation demonstrate specially potential and usefulness, as it is the case of DRM and CCA.

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