Deliverable D2.1 - *Report on the specifications for toolbox methods*

WP2 – Co-design of the supporting toolbox

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HORIZON-MISS-2021-CLIMA-02-01 - Development of climate change risk assessments in European regions and communities based on a transparent and harmonised Climate Risk Assessment approach

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Document History

Deliverable Title	Report on the specifications for toolbox methods
Brief Description	The report describes a diagnostic tool applied to CLIMAAX pilot countries and regions, to review the practices in previous assessments of disaster and climate risks. Furtheremore, it outlines an initial specifications of the risk assessment Toolbox, being prepared and tailormade to the specific needs of the pilot regions.
WP number	WP2
Lead Beneficiary	CMCC – Euro-Mediterranean Centre on Climate Change
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1 Introduction

1.1 Scope

In 2021, the European Commission anticipated the imminent launch of a novel research and innovation (R&I) programme, designed to provide fresh momentum for addressing the significant challenges confronting the EU and the global community. This initiative, denoted as mission-oriented research & innovation, leverages recommendations for the initiation of efforts uniquely tailored to tackle these challenges. In contrast to previous R&I projects, this programme is envisaged to stimulate the direct participation of regional and local authorities, as well as leading innovators, in orchestrating solutions for challenges that have hitherto proved stubborn to traditional approaches. One such challenge selected for this innovative program focusses on climate adaptation at subnational levels, an area previously identified as fraught with persistent impediments linked to financial constraints and limited capacity to scrutinize climate risks and devise appropriate counterstrategies. From 2021 onwards, the European Commission has funded numerous projects, including the CLIMAAX project, with the aim of fostering enabling conditions that are conducive to fast, smart and systemic adaptation, and demonstrating tangible progress through the deployment of multiple innovation instruments.

The CLIMAAX project has been selected as part of a broader initiative to enhance climate literacy and create an environment conducive to risk-informed private and public decision-making. Recognizing that regional climate risk assessments are both limited, inconsistent and often inadequate, and that they are based on a myriad of methodologies and instruments, which may lack transparency for decision-makers, the Mission Implementation Plan[1] has called for the creation of a cohesive framework. This framework, complemented by a suite of practical tools, is intended to encourage, and standardize best practice in this field. The expectation is that a coherent and pragmatic framework, along with a practical, action-oriented toolbox, can assist subnational authorities in investigating the climate-related risks their communities are exposed to and identifying opportunities embedded within early and well-orchestrated adaptation actions. Beyond this, the framework and toolbox are designed to catalyse the ecosystems of climate adaptation, and resilience services. This promotes the development of risk assessments that are tailored to meet specific needs, ultimately fostering a deeper culture of climate risk intelligence.

1.2 Objectives

This report aims to achieve two complementary objectives:

- Firstly, it presents a diagnostic methodology applied to the CLIMAAX pilot countries and regions, designed to consolidate and summarize the efforts previously made in assessing disaster and climate risks. The assessment of current CRA practices in the pilots will provide an improved understanding of the gaps, and how CLIMAAX may contribute to further

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supporting CRAs. This approach acknowledges that none of the pilots are starting from scratch. The diagnostic methodology is constructed upon the existing procedures under the Union Civil Protection Mechanism. The intention is to level the playing field, thereby informing the strategies of the CLIMAAX project.

- Secondly, leveraging the insights and lessons extracted from the review of the current risk assessment practices across Europe (more specifically within the sample provided by the project's pilots), this report will include preliminary specifications for the toolbox. This is important because both the framework and the toolbox are developed in parallel and simultaneously trialled in the project's pilot regions.

This report will contribute to preparing the second phase of the CLIMAAX project. The project is already devising the procedures for selecting fifty or more communities and regions across Europe. The local governments from the selected regions will receive financial support to improve their climate risk assessments, guided by the CLIMAAX recommendations. A description of the toolbox specifications will support the development of the call for applicants to the CLIMAAX Financial Support to Third Parties, developed in WP4.

1.3 Alignment with UCPM

Our approach (i.e. the development of the CRA framework and the toolbox) is aligned with the main EU legislations referring to disaster and climate risk assessments. These are embedded within the regulation that established the Union Civil Protection Mechanism[2] (UCPM) and the recently adopted EU Climate Law[3].

The UCPM is the EU framework promoting collaboration on civil protection to improve prevention, preparedness, and response to disasters. It fosters collective capacity to manage hazards, including natural, technological, and health emergencies. The Mechanism mandates that national risk assessments (NRAs) should be conducted every three years, preferably based on regional disaggregation of risks. This requirement was introduced in 2013, with deadlines set for 2015 and every three years thereafter. The practice of NRAs has been revised in 2019 and 2021 and complemented by guidelines developed by the Joint Research Centre's Disaster Risk Management Knowledge Centre (DRMKC). The 2019 update stipulated that the focus should be on high impact-low probability (HILP) events, including extreme climate events. Based on the national reports received, the European Commission produces an overview of the risks that the EU may face[4]. In addition to this, Member States and Participating States to the Mechanism are obligated to report on their risk management capabilities, defined as capacity to identify, assess, and mitigate risks to acceptable levels. It includes technical, financial, and administrative abilities to conduct risk assessments, develop prevention and preparedness plans, and implement risk mitigation measures[2].

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The EU Climate Law is a landmark legislation passed by the European Union to legally bind its commitment towards achieving a climate-neutral continent by 2050. Article 5 of the EU Climate Law underscores that Member States are obligated to consistently improve their adaptive capacity, build resilience, and decrease their vulnerability to climate change, as articulated in the Paris Agreement. Furthermore, Regulation 2018/1999[5] - governing the Energy Union and climate action - mandates Member States to submit reports detailing their climate change adaptation plans and strategies biennially starting from 2021.

Previously, the practice of climate risk assessment was encouraged as part of the adoption of climate adaptation strategies and plans, included in the 2013 EU Adaptation Strategy. This strategy was revised in 2018 and replaced in 2021. The new Strategy emphasizes more sophisticated climate risk assessments, considering compound, cascading, transboundary, and remote risks, which were previously overlooked. Complementing these efforts, the European Environment Agency (EEA) has provided an overview of Climate Change Impact and Vulnerability assessments (CCIV), with the latest editions dating back to 2018. The EEA continues to produce an annual update on some climate-impact drivers as part of their monitoring activities, represented in the core set of indicators (CSI) and the climate state and impact indicators (CLIM). To complete the overview, the obligation to report and release information also applies to business entities as part of their financial and non-financial disclosures. It also extends to critical entities responsible for managing infrastructure that provides essential services. This latter obligation was recently introduced by the CER directive[6]. Finally, the Floods Directive, introduced in 2007[7], makes it mandatory to Member States to assess flood risks and devise flood risk management plans.

1.4 Approach

Informed by the above reports where available, and other policy and scholarly literature, our review takes an analytical stance on the practice of disaster and climate risk assessments within pilot countries and regions. For this purpose, we use a peer-review framework devised for a comparable purpose. This framework is explained in depth in section 2.

The structure of the report is as follows:

Section 2 presents the UCPM **peer review assessment framework,** outlining its scope, practice, and the framework utilized for this purpose. Within the CLIMAAX scope, only a portion of the Framework – pertaining to risk governance and risk assessment components – is applied. The original Framework was designed to encompass disaster risk assessment with climate risks as an integral part. Given that the climate components of National Risk Assessments (NRAs) do not capture all climate-related risks to the same extent as Climate Risk Assessments (CRAs), we have applied the framework to consolidate information from both policy domains.

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Section 3 provides a **summary of the desk review,** where we apply the UCPM framework to assess the status of CRAs in the CLIMAAX pilot areas. A desk review is a crucial component of the peer review process, conducted by the facilitators appointed by the Directorate-General for European Civil Protection and Civil Aid Operations (DG ECHO). For the purposes of the CLIMAAX project, the findings from the desk review have been disseminated to a wider array of organizations in each pilot country, which contribute to or are involved in the pertinent assessments. These desk reviews serve to stimulate discussions and dialogues organized under WP1. Through these consultations, the desk reviews are refined and completed, and the stakeholder organizations are integrated into the community of practice established in WP1.

Section 4 provides an overview of the **toolbox specifications** that form the basis of the CLIMAAX Toolbox. It is structured as a sequence of workflows used when carrying out a climate risk assessment.

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2 The UCPM Peer Review Assessment Framework for climate risk

In this section we explain the background (Section 2.1) and main components of the UCPM Peer Review Assessment Framework for climate risk (Section 2.2)

2.1 Practice of peer review for risk and resilience capabilities

Peer review is a recognized method for assessing policy performance and tracking its implementation progress. Engaging experts in policy evaluations encourages dialogue and knowledge exchange while assessing outcomes and methodologies for performance assessment. Scientific literature on peer review was limited and an agreed definition was missing until 2020 when a guidance was published as the ISO 22392:2020 standard developed by the Technical Committee ISO/TC 292 Security and resilience. According to that standard, peer review entails a reviewer examining a host's performance, offering feedback on an analysis area, and gaining valuable lessons for application in their own context. The Organisation for Economic Co-operation and Development (OECD) used the method since early 2000s[8], for assessing progress made in various policy areas, including civil protection and risk management. The method was also adopted by other international organisations and UN agencies, to monitor progress e.g. on Sustainable Development Agenda.

Within the EU context, peer reviews serve as collaborative tools to promote mutual learning and knowledge dissemination. Peer reviews are used notably in national labour market policies and the research and innovation, helping to devise the Smart Specialisation (S3) Strategies[9]. In the disaster risk and civil protection context, the peer review was started as a joint initiative of the EC, OECD and the United Nations Office for Disaster Risk Reduction (UNDRR). The UCPM introduced peer reviews as a means of assessing Member States' and Participating States[a]' risk management capabilities. The peer reviews cover all aspects of the integrated Disaster Risk Management (DRM): prevention, preparedness, response, and recovery and lessons learned. Since 2013, the DG ECHO has managed a peer review programme allowing countries to evaluate their preparedness for risks and identify risk management improvements. Sixteen countries have voluntarily participated since the programme's inception.

Throughout the EU peer review program's cycles, various assessment frameworks have been established to facilitate the process. Experts from OECD and UNDRR were engaged from the outset to optimize the program, leveraging existing good practices and incorporating recommendations from past global reviews. This collaboration between the EC, UNDRR, and OECD has progressively refined the process, benefiting volunteer countries, involved peers, and the UCPM.

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[a] UCPM Participating States: Albania, Bosnia and Herzegovina, Iceland, Montenegro, North Macedonia, Norway, Serbia, Türkiye, and Ukraine.

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The most up-to-date framework for peer review (PRAF)[10] of risk management capabilities was developed in 2020 and applies ever since. The framework delineates key elements, such as involved actors, roles, responsibilities, phases, and the analytical structure for the technical analysis, providing direction throughout the process stages. This crucial document guides the experts and the reviewed country, ensuring comprehensive, effective, evidence-based, and comparable analysis. The PRAF balances various, sometimes conflicting, key elements. It is clear, comprehensible, and aligns with the UCPM legislative framework, using globally and regionally recognized terminology. The Framework is comprehensive yet simple, and adaptable to the unique requirements of each review. The Framework is revised based on systematic ex-post analyses after each program cycle to identify gaps and good practices, striving for continuous process and program improvement.

2.2 Structure of the Peer review Framework

The analytical framework, a central pillar of the Peer Review Assessment Framework (PRAF), is a modular structure designed to guide the review process. This ensures flexibility and adaptability to the specific needs defined within each review's Terms of Reference. The PRAF identifies seven crucial topics for the analysis (hexagons in Figure 1): (1) risk governance, (2) risk assessment, (3) risk management planning, (4) risk prevention, (5) risk preparedness, (6) emergency response, and (7) recovery and lessons learned. This covers all stages of the disaster risk management (DRM) cycle and includes ex-post assessment of recent disasters and crises. Each area of analysis, as shown in Figure 1, is further divided into six topics.

Risk governance (central violet hexagon in Figure 1) is a central element in a review of disaster risk management capabilities, and it should be assessed in every review. The host countries can select specific thematic areas and topics within those areas to tailor the peer review to their needs. Each sector of analysis consistently includes two key topics: framework & processes, and capabilities. The former aids peers in examining the legal framework and processes underpinning each area, while the latter guides them in evaluating capabilities. Notably, the UCPM regulation specifies that risk management capability assessment should consider technical, financial, and administrative capacity to carry out risk assessments, risk management planning for prevention and preparedness, and risk prevention and preparedness measures.

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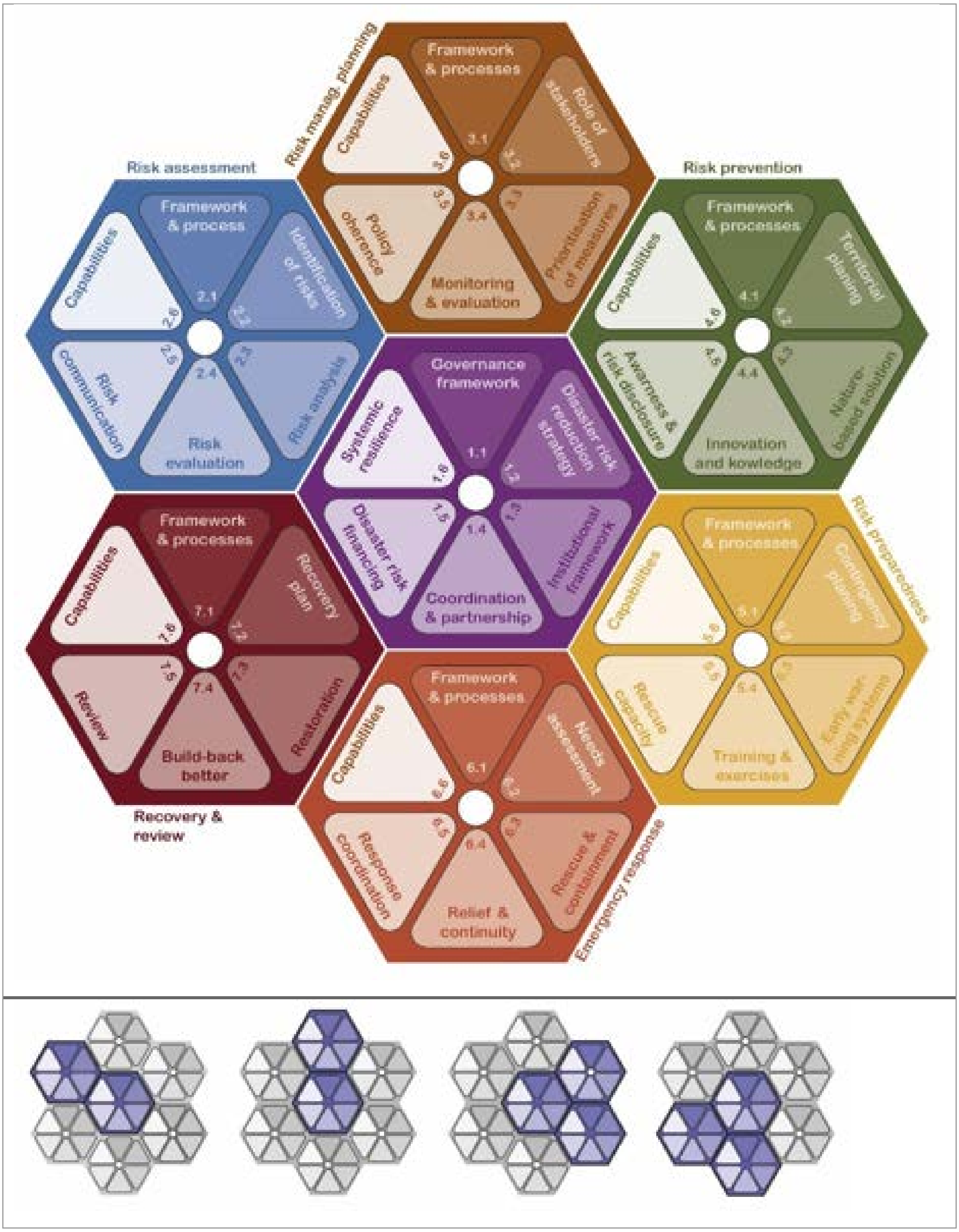

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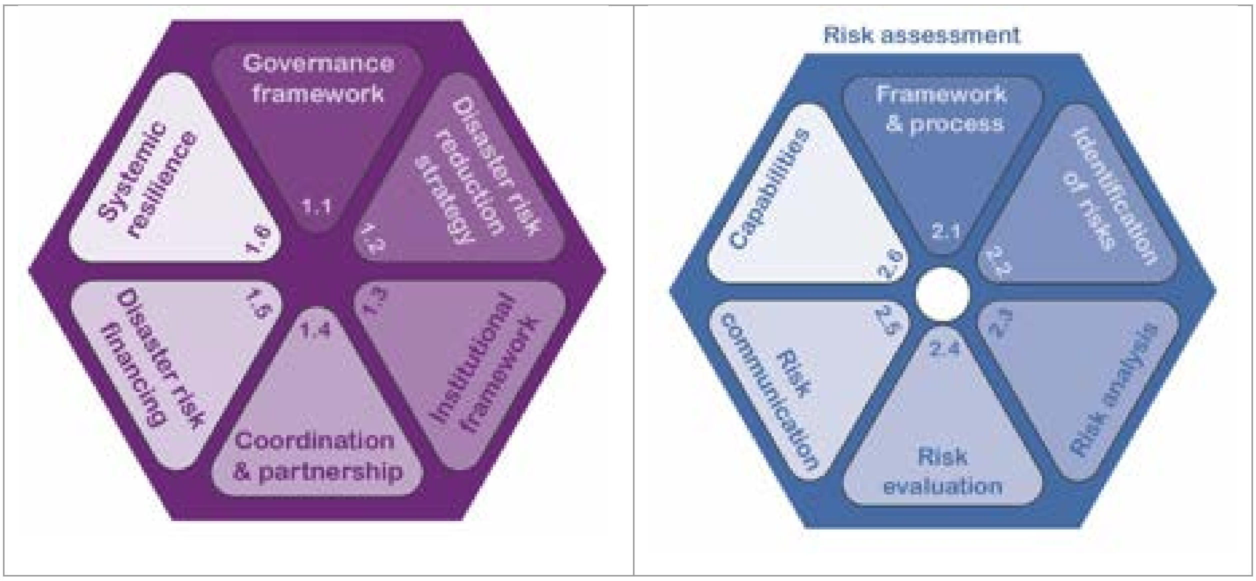

Figure 1: Peer Review Assessment Framework (upper panel all thematic areas; middle panel – possible thematic focus areas; lower panel – detail on risk governance and risk assessment). The PRAF can be used to conduct all policy areas or a combination of them. The upper panel shows the recommended areas for a targeted partial or thematic peer review.

Risk Assessment (blue hexagon in Figure 1) focusses on established process at the national and/or sub-national level. The analysis delves into the legal and procedural framework guiding the assessment process, including three key stages of risk assessment: identification, analysis, and evaluation of risks. Furthermore, the analysis considers the communication, dissemination, and data sharing processes of the risk assessment outcomes, evaluating their immediate applicability in various fields. The analysis also covers emerging, transboundary, and low probability but high impact risks, as these are key components of UCPM national risk assessments.

Risk management planning (brown hexagon in Figure 1) looks at planning processes for risk reduction and management in place at national and/or sub-national level. The analysis covers the engagement of key stakeholders, the methods for identifying and prioritising measures, and the monitoring, evaluation, and reporting processes. Policy coherence with other frameworks and related planning processes linked to disaster risk reduction, such as the Paris Agreement and Sustainable Development Goals (SDGs), is also addressed.

Risk prevention (green hexagon in Figure 1) covers measures aimed at reducing risks or mitigating their adverse consequences. The analysis focuses on the overall framework underlying the identification and implementation of measures and examines some key prevention measures, such as territorial planning, structural measures, and Nature-Based Solutions (NBS) and risk awareness and communication processes. This section also looks at the identification of innovation and knowledge services and their exploitation in supporting and informing DRM activities.

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Risk preparedness (yellow hexagon in Figure 1) looks at measures aimed at establishing a state of readiness needed to ensure an effective, rapid response to a disaster event. Similar to the prevention section, the analysis focuses on the overall process that supports the identification and implementation of key preparedness measures, identified as contingency planning processes, early warning systems in place, training, exercises, and development of response capacities.

Emergency response (orange hexagon in Figure1) covers activities and processes to respond to a hazardous event, focussing on processes for assessing needs, response operations and vertical and horizontal coordination processes among responsible authorities and key stakeholders.

Recovery and lessons learned (red hexagon in Figure 1) addresses the post-disaster phase and investigate the implementation of recovery and restoration plans, the build-back-better adaptation and climate proofing processes, and the lessons learned procedures in place to identify good practices, areas for improvement to mitigate risk and strengthen resilience.

These assessment topics guide either a comprehensive peer review of all aspects of risk management capabilities or only specific ones. Countries can opt for a focused review of areas they consider most critical for their policy goals. Figure 1 illustrates the potential combination of topics/hexagons that can facilitate a targeted peer review.

In this report, specifically in the following section 3, we have used the PRAF framework to evaluate risk governance and risk assessment topics within the project pilot areas. In doing so, we have enhanced the assessment by incorporating insights from disaster risk governance under the Union Civil Protection Mechanism (UCPM), as well as climate risk assessments outlined in the EU Climate Adaptation Strategy and Climate Law. The extension was performed by the same team who initially develop the PRAF for the purpose of UCPM. This ensures the compatibility and consistence of the Framework.

Disaster risk reduction (DRR) and climate change adaptation (CCA) are closely related areas of policy, innovation, and practice, with shared values, principles, and challenges. Both DRR and CCA impact all aspects of governance and society, emphasizing resilience as both a prerequisite and a result of risk-aware development. Their convergence and incorporation into other policy realms have been widely deliberated and analysed. Cross-discipline learning, and knowledge exchange have propelled advancements in both sectors. The comprehensive risk analysis approach integral to holistic, multi-hazard risk reduction has guided and influenced adaptation efforts. Effective decision-making, focused on strategies adaptable to various greenhouse gas emissions and socio-economic scenarios, offers valuable insights for DRR. Furthermore, both DRR and CCA serve as catalysts for transformative action and change and share a focus on addressing underlying vulnerability factors and highlighting the role of individuals and organizations in driving personal and societal transformations. Achieving transformational change demands fresh commitments, insights, and innovative means to involve people at every stage.

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3 Desk reviews

3.1 Introduction

Sections 3.2-3.6 analyse disaster and climate risk governance and assessment in the pilot countries and regions. The analysis relies on literature and desk reviews, following the framework for peer review assessment of risk management capabilities (PRAF) introduced in section 2. The desk review draws from a diverse array of information sources, including national and regional disaster risk assessments submitted as part of the UCPM risk mapping; available climate vulnerability, impact, and risk assessments; national communications within the UNFCCC process; voluntary reports on Sustainable Development Agenda implementation; as well as other EC documents like those mandatory for various EU directives or EC's sets of recommendations for the European Semester and Recovery and Resilience Facility (RRF). Additional sources, including OECD assessment reports, have also been considered. The desk review predominantly relies on national policy and legislative documents that the review team obtained. Annex 1 provides an overview of the primary information sources used for the desk review's objectives.

The draft desk reviews were shared with the project partners representing the pilot regions as well as the organisations within the pilot countries identified throughout the desk review. The sharing of the desk review served a twofold purpose: First, to verify the information collected through the desk review, correcting any misinterpretations by the review team, and complementing the insights with information not yet accessible or located. Second, to involve various stakeholders within the CLIMAAX consultation process and establish a community of practice (CoP) spanning the pilot countries and regions. In close collaboration with WP3 (Regional CRA prototypes and operationalization) and WP1 (Framework for local and regional climate risk assessment), the desk reviews have been or will be deliberated in country-focused virtual or physical meetings. These consultations will persist, amalgamated with the Community of Practice (CoP) established as part of WP1.

3.2 Finland

Finland, a parliamentary republic, is bordered by Sweden, Norway, and Russia, with the Baltic Sea to its south and southeast. Spanning 338,455 sq.km and home to 5.6 million people, the country is largely populated in the south, with sparse settlements in the north. Åland, an archipelago, is a Swedish-speaking autonomous region with a permanent elected regional council. The northern part of Finland hosts semi-autonomous Sami Domicile Areas to preserve the language and culture of the Sami people. The country is divided into 19 regions and 309 municipalities. Municipalities are the basic subdivisions, housing local governments, while regional councils, composed of delegates from municipal councils, oversee the regions. Regional councils are responsible for regional planning, enterprise development, and education. Since January 1, 2023, Finland has also introduced

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wellbeing services counties, which are separate public bodies responsible for social and health care, as well as rescue services. The highest decision-making authority within counties rests with the county councils, which are elected every four years.

3.2.1 Risk governance

3.2.1.1 Governance framework

The legislative framework for disaster risk reduction (DRR) is comprised by the Rescue Act (379/2011), Disaster Risk Emergency Powers Act (1552/2011), and Act on Security of Supply (1390/1992). The Rescue Act outlines the tasks of rescue services and the authority's powers at national and local levels. The Emergency Powers/Readiness Act addresses emergency powers in exceptional circumstances, protecting national economy, law and order, citizens' basic rights, and territorial integrity. The Act on Security of Supply focuses on ensuring the availability of essential goods and services during crises. The roles and responsibilities for managing crises and emergencies involve state and sub-national governance authorities, as well as individuals, businesses, and other entities. Other risk-related legislative acts include the Water Act (2011/587), Land Use and Building Act (132/1999), amended in 2023 by the Construction Act, and the Flood Risk Management Act (620/2010), which implemented the EU Floods Directive.

National adaptation planning has been stipulated as part of Finland's Climate Act, firstly adopted in 2015 and reformed in 2022 (423/2022). The Climate Act provides a framework for planning, implementing, and assessing climate policies and improves cooperation among government offices in mitigation and adaptation. The 2022 reform of the Act encompasses the carbon neutrality target for 2035[b], along with emissions reduction targets for 2030, 2040, and 2050. These targets aim for reductions of 60%, 80%, and at least 90 or 95%, respectively, compared to the levels of 1990. The Act stipulates that a national adaptation plan must be approved at least every ten years or every other electoral period, with evaluations conducted midway through the implementation period. Climate change adaptation is integrated into Finland's national policies, including the Strategy for Arctic Policy, adopted in June 2021, where climate change mitigation and adaptation is one of the four priorities.

Finland's development policy focuses on reducing poverty and inequality while promoting sustainable development. The country's cross-cutting objectives include gender equality, non-discrimination, climate resilience, low emission development, and environmental protection.

[b] Finland's goal is to achieve climate neutrality by 2035 and become the first fossil-free welfare society. This implies balancing human-caused emissions with greenhouse gas removals, effectively equating carbon output and sequestration. See for more information: State Treasury 2021, link, accessed on 01/06/2023

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3.2.1.2 Comprehensive disaster risk reduction and climate change adaptation strategies

Finland's Disaster Risk Reduction (DRR) is incorporated within various strategies, notably the "Security Strategy for Society (SSfS)" established in 2003 and updated in 2006, 2010, and 2017. The SSfS outlines national preparedness principles for different types of emergencies, guiding administrative actions and promoting collaboration between citizens and authorities through information sharing, joint planning, and cooperative actions. The Strategy defines seven vital functions that must be safeguarded at all operational levels.[c] It also outlines the responsibilities of government ministries in preparedness planning, with 57 specific tasks and areas of responsibility identified to protect the vital functions. The SSfS is closely aligned with national risk assessment, thereby informing preparedness planning at national, regional, and municipal levels. Complementary to the SSfS, the Internal Security Report evaluates Finland's internal security status, considering national and global factors influencing it. It outlines objectives and the development direction until 2030. Climate change is one of the factors affecting internal security.

Finland adopted six national energy and climate policy strategies in the years 2001, 2005, 2008, 2013, 2016, and 2022. As one of the first EU member states, Finland implemented a national climate adaptation strategy (NAS) in 2005, which was reassessed in 2013 and replaced by the National Climate Change Adaptation Plan (NAP) the following year. The Plan targets bolstering Finland's capacity to manage and adapt to climate change, focusing on integrating adaptation into sectoral activities, providing necessary climate change management tools, and enhancing societal resilience through research, innovation, and public awareness initiatives. The mid-term review of the Plan was conducted in 2018-2019, while the final evaluation was completed in 2021-2022. The development of the NAP 2030 is in progress.

3.2.1.3 Institutional framework

Disaster risk management and civil defence is a multi-level governance system involving national, regional, and local entities along with non-governmental organizations. The national level, led by the Ministry of the Interior, sets policies, regulations, and guidelines for managing various hazards. The regional rescue authority collaborates with the national government and local municipalities for efficient disaster response. Local municipalities implement these policies and coordinate with volunteer organizations to enhance community resilience. This system underscores the importance of cooperation and coordination at all levels for effective disaster management.

Under the Emergency Powers Act, the government, state administrative authorities, state businesses, municipalities, and other state authorities are obligated to ensure the least disruption

[c] Vital functions of society involve cross-sectoral tasks shared by multiple parties, forming the foundation for preparedness planning at all levels. These include including leadership, international and EU activities, defence capability, internal security, economy, infrastructure, security of supply, functional capacity of the population and services, and psychological resilience

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in their duties, even in emergency conditions, through emergency plans and preparation. The Rescue Act mandates building owners, occupants, and business operators to prevent dangerous situations, protect individuals, property, and the environment, and facilitate rescue operations. The Act also outlines the duty of various authorities to participate in rescue operations and collaborate in preparing rescue plans.

The Regional State Administrative Agencies are responsible for coordinating regional preparedness and fostering cooperation with authorities, non-governmental organizations, and the private sector. They conduct large-scale preparedness exercises and utilize regional risk assessments to enhance regional risk management capabilities and support preparedness planning and training activities.

The Climate Act assigns implementation and monitoring of climate plans to each ministry. The Ministry of the Environment holds the responsibility for coordinating the preparatory work for the climate negotiations and is the national focal point for the UNFCCC. The Ministry of Agriculture and Forestry coordinates national adaptation policy. Sector ministries are responsible for conducting climate risk and vulnerability assessments and developing sector-specific adaptation plans as needed. The sectoral plans consist of the Ministry of Environment's Action Plan, Ministry of Agriculture and Forestry's Adaptation Action Plan, and Ministry of Social Affairs and Health Adaptation Plan.

Regionally, climate efforts are primarily driven by the Regional Councils and Economic Development, Transport, and Environment Centres (ELY Centres). The Regional Councils compile regional Land-Use Plans regulating urban structure and specific area use, and incorporate climate and energy issues into their strategies, either through distinct climate strategy documents or as part of comprehensive regional strategies. The ELY Centres, steered by the Ministry of Employment and the Economy, handle tasks related to multiple ministries including the environment, transport and communications, agriculture and forestry, education and culture, and the interior. ELY Centres are tasked with the regional implementation and development of central government initiatives.

The Climate Act requires municipalities to create climate plans that outline objectives and measures to reduce their greenhouse gas emissions. Local governments within their municipality oversee zoning, land use, transport planning, control of their energy companies, selection of heating systems for buildings, and public procurement in their territories.

3.2.1.4 Coordination and partnership

The Ministry of the Interior established the National Platform for Disaster Risk Reduction in 2010 to comply with the UN Hyogo Framework for Action. It was later reestablished as the National Sendai Network in 2021, serving as a platform for 26 stakeholders involved in implementing the Sendai Framework for Disaster Risk Reduction 2015-2030. The network includes ministries, research and development institutions, central national agencies, and non-governmental organizations. Its

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objective is to enhance cooperation, information sharing, and implementation efforts at national and international levels.

As for climate policy, Finland established the platform Climate Policy Roundtable in 2020, bringing together key stakeholders such as trade unions, municipalities, scientists, industrial sectors, interest groups, young people, and NGOs. It serves as a network that supports the preparation and implementation of Finland's national climate actions. The Roundtable meets regularly, typically five to seven times a year, to facilitate discussions and contribute to climate policy processes. In April 2021, a nationwide online Citizens' Jury was held to discuss and assess climate actions proposed by the Finnish government. The jury, organized by the Climate Policy Roundtable and the Ministry of the Environment, marked the first deliberative mini-public gathering on climate issues in Finland.

The Finnish Climate Change Panel, formed in December 2011 and subsequently anchored by the Climate Change Act, bridges research and policymaking. It includes experts from diverse scientific fields and offers scientific advice, opinions on policy plans, and reports to support climate policy making and legislation in Finland.

The Ministry of Agriculture and Forestry supervises the Monitoring Group for Climate Change Adaptation. The group includes representatives from relevant ministries, authorities, regional and local entities, research institutes, and specialized organizations in fire and rescue services and financial services. The group collaborates on compiling key indicators for monitoring climate impacts, risks, and adaptation.

In 2020, Finland's Regional Councils established a collaboration network to enhance knowledge sharing and cooperation regarding climate issues, including climate change adaptation. The regional Centres for Economic Development, Transport and the Environment have conducted thorough assessments of present and future adaptation requirements within their respective domains. Through their internal climate change network, these centres coordinate nationwide efforts, while many regions collaborate with other regional actors to develop adaptation plans.

3.2.1.5 Disaster risk financing

Disaster risk and climate finance encompass various sources, including funds from the central government, regional and local tax revenues, private funding, and commercial insurance. The government has committed to earmarking an annual budget of 2,631 million Euros for the development of climate plans at the municipal level.[11] As per the Protection Gap Scoreboard, Finland exhibits a high degree of insurance coverage availability and uptake, with an insurance penetration rate between 50 and 75%.[12]

Finland's international climate finance is integrated into its development cooperation, with a focus on both mitigating and adapting to climate change. In 2019 and 2020, Finland allocated around 0.41% and 0,47% of GNI (gross national income) to development aid.[11] Finland has incorporated

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investment-based and loan-based climate finance alongside traditional grant-based finance since 2016. As per the current Finnish government policies, 75% of the investment- and loan-based Official Development Assistance (ODA)[d] finance must be directed towards climate action.

3.2.1.6 Systemic resilience

Finland is top ranked according to various systemic resilience indices such as the ND-GAIN, Inform RISK, INFORM Climate and Human Development Index (HDI). ND-GAIN Index combines a nation's vulnerability to climate change and other global threats with its preparedness to enhance resilience. The Index ranks Finland second out of 182 countries, with a vulnerability subindex of 11th and a readiness subindex ranking of fourth. The INFORM Risk Index places Finland third in risk exposure based on various indicators related to prevention, preparedness, and response to humanitarian crises and disasters. Its counterpart, INFORM Climate, ranks Finland within the top ten countries. The Human Development Index (HDI) categorizes Finland as a country with very high human development. The Security Strategy for Society (SSfS) underscores psychological resilience as a critical societal function, denoting the capacity of individuals, communities, and society to resist and bounce back from crisis impacts. This necessitates cross-sector collaboration to safeguard independence, well-being, and security of the population.

3.2.2 Risk assessment

3.2.2.1 Legislative framework and processes

Finland's risk assessment system, spanning national and regional levels, integrates climate change considerations in laws like Acts 2011/587 (water resources), 1999/132 (land use), 2010/620 (flood risk), and 1552/2011 (emergency powers). These mandate up-to-date sectoral risk assessments and clarify roles between state and regional authorities. The Emergency Power Act requires municipalities to ensure minimal disruption during emergencies via preparedness plans. Similarly, the Flood Risk Management Act mandates stormwater management. Other sector-specific legislations, like the Health Protection Act and the Food Act, also impose risk assessments and preparedness duties on municipalities. The Rescue Act, based on regional risk analysis, requires rescue services to align with local needs and accident threats.[13]

The first national risk assessment was prepared in 2015; the second was published in 2018 and then revised in 2022–2023. Its main aim is laying the foundation for preparedness planning at all operational levels in line with the SSfS. Therefore, the National Risk Assessment (NRA) methodology is carried out in relation to the vital functions of society. The Ministry of Interior oversees the NRA, leading cross-sectoral groups that included representatives from all ministries, the National Emergency Supply Agency, the Finnish Meteorological Institute, Regional State Administrative

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[d] Official development assistance (ODA) is defined as government aid that promotes and specifically targets the economic development and welfare of developing countries.

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Agencies, and NGOs. The NRA was compiled by considering existing risk assessments from these different actors. Regional risk assessments, led by rescue departments and Regional State Administrative Agencies, are conducted alongside the national risk assessment. These regional assessments focus on region-specific threats, involving a cross-sectoral process with local municipalities, wellbeing services counties, authorities, businesses, and organisations. Each participant concentrates on risks pertinent to their sector and activities.[14]

Effective horizontal coordination is demonstrated by the active involvement of major authorities and stakeholders in the risk assessment process. Both the national and regional risk assessments are developed through cross-administrative cooperation, engaging different stakeholders and authorities. In the 2018 NRA, each threat scenario or disruption was described by the responsible ministry in collaboration with experts from relevant administrative branches.[15] In the assessment revision of 2023, previous data was reviewed through cross-sectoral cooperation, with participation from ministries, the National Emergency Supply Agency, the Finnish Meteorological Institute (FMI), Regional State Administrative Agencies, and NGOs in the working groups.[14]

The NAP 2030, prepared by the Ministry of Agriculture and Forestry, served as a key source for the NRA. Released in 2022 under the Climate Change Act, the Plan offers comprehensive details on climate-related risks, drawing on a wide-ranging risk and vulnerability assessment from the SIETO project ("Assessment of weather and climate risks"), coordinated by the FMI. Several institutes, including the FMI, Finnish Environment Institute (SYKE), Finnish Institute for Health and Welfare (THL), and Natural Resources Institute (LUKE), contribute to assessing climate vulnerability and risks. As per the 2022 Climate Act (Act 432/2022), an independent advisory body, the Finnish Climate Change Panel, contributes to integrating scientific advice into climate risk assessments. Research is guided by a government plan that directs activities towards priority areas and facilitates extensive use of research data in government decision-making.

3.2.2.2 Risk identification

The NRA focuses on significant risks with potential widespread impact on society's vital functions, targeting sudden disruptions that require crisis resilience. Slowly developing risks, such as demographic changes or climate changes, are not extensively covered. Climate-related risks are addressed in terms of their potential to disrupt Finland's ecosystems, public health, businesses, and critical infrastructures. A specific subchapter on climate change in the NRA outlines both internal and external climate-related risks. However, these risks are believed to have a regional nature and are examined more comprehensively in regional risk assessments, which clearly identify climate change impacts, such as extreme weather events, natural disasters, and disruptions to power and water supply.[13]

The 2023 NRA identifies 21 threat scenarios, with climate change discussed in the contexts of energy and water supply disruptions, large-scale wildfires, and external risks such as disruptions in food

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production, migration triggers, financial market impacts, national supply security, transition risks, and potential causes of civil disturbances. Climate change effects on critical infrastructure, like ice melting affecting Baltic Sea transport, are also mentioned. The 2023 NRA builds upon data from sector-specific risk assessments, projects, and literature, with the 2022 National Climate Change Adaptation Plan being a key source. The Plan incorporated information from projects like SIETO (2018), which created an assessment report on weather and climate risks in Finland, and the SUOMI project ("Climate change adaptation: regional aspects and policy instruments"). Both projects, coordinated by the FMI, relied on literature, expert views, and recent sectoral assessments.

3.2.2.3 Risk analysis

The NRA includes threat scenarios and disruptions in a structured manner, including a verbal description, the target, the potential realization, and the impact assessment. The impact assessment is graphically summarized using a scale ranging from no impact to minor, significant, and severely compromising impacts. In the 2018 NRA, the impact assessment included the classification of direct or indirect impacts on vital functions and the trend of likelihood (increases, decreases, or remains unchanged). In regional risk assessments, key threats and disruption scenarios are qualitatively analysed, and the results are presented in a risk matrix along with a compilation of risk analysis.

In the SIETO assessment report, a sector-specific analysis of weather and climate risks and vulnerabilities was conducted in sectors such as biodiversity, water resources, natural resources, energy, built environment, industry, finance, insurance, and health (see Box 1). Remote effects, which involve climate variability outside Finland's borders impacting the country, were also analysed. The report identified the most significant national-level climate risks, including risks with cross-sectoral impacts and risks with information gaps due to high adaptation costs or identification shortcomings. The climate risk assessment built upon the IPCC AR5 Framework. For this purpose, simulations from 28 global (CMIP5) and regional (EURO-CORDEX) models were used, covering four different RCPs (2, 4.5, 6, 8.5), and time periods from 2000 to 2085 compared to 1971 to 2000. Government institutes collaborated to apply the RCP-SSP framework for Finland and its specific sectors, as part of activities related to scenario building. The assessment is based on assumptions about average climate change and stable social development but recognizes the importance of alternative social developments. Two future socio-economic development scenarios on climate risks were created, an optimistic scenario with effective management of challenges and a pessimistic scenario with high inequality and a weak economy. These scenarios demonstrate how exposure and vulnerability can vary depending on future societal development.[16]

- **Biodiversity**: The SUMI project, ("Finnish protected area network in a changing climate", 2017-2019) identified climate risks related to shifts in species and habitats, increased threats

- In the **built environment**, flood risks are evaluated based on damage statistics from the Finnish Environment Agency, with a focus on heavy rain-induced floods across different

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to endangered species, ecosystem service degradation, and alien species spread.

- **Water resources**: Key climate risks include increased stormwater and seawater floods, and droughts. The WaterAdapt project (2012) evaluated the impacts of climate change on Finland's hydrology, water resource, and regulatory practice, changes in river flows, water levels, groundwater, and the effects on lake usage and conditions.

- Risk assessment focusing on **agriculture**, **forestry**, fish farming, game, and reindeer is detailed in the "State of Adaptation" report (2017).

- The **Energy and infrastructure** sectoral risk assessment identified major climate risks including disruptions in energy transmission and distribution and interruptions energy production.

regions. Floods caused by sea level rise and coastal conditions are assessed using international ocean level rise scenarios, which show the projected changes in flood levels along coast.

- In the **transport system**, risks are evaluated from studies on past extreme weather events causing damage to Finnish roads, car crashes linked with extreme weather, and impacts on the logistic sector. Air traffic risks are assessed through probabilistic scenarios of adverse weather conditions.[e]

- **Finance and insurance** risks are monitored by the Bank of Finland, and forest-related risks such as fires and heavy snowfall are assessed using combined climate models and observational data.[f]

Box 1: Sector-specific analysis of weather and climate risks as reported in the SIETO assessment report.

The Centre for Economic Development, Transport and the Environment (ELY Centre), in partnership with the Flood Center of the FMI and SYKE, produced maps detailing significant flood risk areas in Finland. This work was part of a broader analysis included in the final report of the SUOMI project (2020-2022), an initiative led by the FMI that concentrated on regionally specific climate risk assessments for 1991-2020 and critical risks for 2020-2050. The report presented scenarios showing potential changes in temperature and precipitation based on various greenhouse gas emission trends up to 2100, using the 1981-2010 climate period as a baseline.

The SUOMI report also included data on sea ice changes, drawing on previous studies and the results of the SmartSea project. It provided detailed insights into changes in different sea areas up to 2050,

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[e] The studies are available at the following links: https://julkaisut.valtioneuvosto.fi/handle/10024/78186; https://helda.helsinki.fi/items/c262eb80-c199-44a1-bcde-ebbb1e1ef61a; https://helda.helsinki.fi/items/b6af90a1-ba17-4fba-a5d2-fb32068bb4cf

[f] See the FMI report available at https://helda.helsinki.fi/items/b6af90a1-ba17-4fba-a5d2-fb32068bb4cf

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considering factors related to the sea, load, land uplift, and sea ice. The report highlighted both individual and combined risks.

Additionally, the SUOMI project examined the economic implications of climate change adaptation, including an analysis of the impacts on Finland's economy. The report includes a summary of the costs associated with key extreme events like water and coastal flooding.

3.2.2.4 Risk evaluation

Risk evaluation criteria are based on a scale ranging from no impact to minor to significant and severely compromising impacts and are assessed in relation to the vital functions of society as defined in the 2017 SSfS. Minor impacts denote short-lived, regional effects that are limited or indirect on the operation and maintenance of one or more strategic tasks. Significant impacts have national importance on the upkeep of strategic tasks, potentially requiring measures beyond the norm. Extreme impacts are large-scale and compromising to strategic tasks, potentially requiring additional powers to manage the situation and safeguard strategic tasks. Risk assessment evaluations are conducted every six months, as stated in the SIETO assessment report. The second report of the SIETO project introduces an operational framework for regularly updating weather and climate risk assessments.

3.2.2.5 Risk communication

Access to information in official documents is a fundamental civil right protected by the Finnish constitution. The Act on the Openness of Government Activities (621/1999) guarantees the right to information on public officials' activities, with access to documents as the main principle. The Finlex online database provides public access to current legislation on climate and energy in Finland. The results of the NRA and regional risk assessments are made public and shared with the authorities, media, and relevant stakeholders. They are accessible on the Ministry of Interior's website, and regional risk assessments are also distributed as written reports to regional operators. These assessments are presented at events attended by actors from the public, private, and third sectors at both the national and regional levels. The aim is to use these documents for preparedness planning[14]. The National Climate Change Adaptation Plan (2022) aims to provide all actors with access to climate change assessment and management tools.

3.2.2.6 Administrative, financial and technical capabilities

The national risk assessment system in Finland involves various stakeholders and authorities, including experts from ministries' administrative branches and government research institutes. However, gaps in information on climate-related risks remain a challenge. Improving knowledge on climate risk assessment is a priority in the National Climate Change Adaptation Plan and the government's common foresight work.

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3.3 Latvia

Latvia is a state in the Baltic Region of Northern Europe, bordering Estonia to the north, Russia to the east, Belarus to the southeast, Lithuania to the south, and the Baltic Sea to the west, where it shares a maritime border with Sweden. Latvia's territory covers an area of 64,573km2 and its population amounted to 1,893,223 in 2021.[17]

Latvia is a typical lowland country, and its terrain is characterised by flat, low areas and hilly elevations; the highest point of the country is Gaiziņkalns, a 311m high hill. Its territory was formed during the Pleistocene ice age, when soil and debris were pushed by glaciers into mounds and hills, also contributing to the formation of glacial moraines, eskers, and drumlins. Nowadays more than 40% of Lavia's territory is covered by woods: in 2015 Latvia's total forest area was 32,983.6 km2, cropland 17,161.1 km2 and grassland 7,380.7 km2, wetland 4,451.8 km2, settlements 2,541.4km2.[18] Latvia has more than 3,000 lakes and 12,000 rivers. Its coasts are sandy and rich in dunes, lagoons and lakes.

The administrative division of Latvia has undergone an organisational change since 1 July 2021. Latvia's territory is currently subdivided into 43 local government units, consisting of 36 municipalities (*novadi*) and seven state cities (*valstspilsētas*). According to the 2009 Law on Public Agencies[19], amended in 2021, all local governments have the same competencies aside from the capital city of Rīga, which fulfils a range of additional functions. The state has full legislative power, which is shared with the local governments in the fields of spatial planning, infrastructure management, public transport, economic policy and development, welfare, and school education. Municipalities and state cities also have the responsibility of registration services, public order and civil protection, environment issues, public utilities, upkeep of public areas, housing issues, culture, health, and social welfare.[20]

3.3.1 Risk governance

3.3.1.1 Governance framework

The legislative framework that regulates the disaster management system of Latvia is organised according to the Civil Protection and Disaster Management Law (Law No. 100 (5672)/2016), which determines the mandate of the civil protection system and disaster management subjects to ensure the safety and protection of people, the environment and property in case of a disaster or threats.

The civil protection system is part of the national security system, which is formed by the national and local government authorities. The prime minister is responsible for the functioning of the system and the implementation of tasks, while the State Fire and Rescue Service of Latvia, subordinated to the Ministry of Interior, manages, coordinates, and controls the operation of the system and civil emergency planning, according to law 398/2010 on the "Regulation of the State Fire and Rescue Service".[21]

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Regarding sectoral regulations dealing with the management of specific hazards, the Regulations Regarding Preliminary Flood Risk Assessment, Flood Maps and Flood Risk Management Plan (Cab. Reg. No. 1534/2009) transposed the EU Floods Directive on the assessment and management of flood risk into the national legislation.

In 2022, the State Audit Office of Latvia conducted an audit to assess the readiness and performance of the civil protection and disaster management system; results were published in a report which focuses on the gaps of the system and provides recommendations. In the report, it is argued that civil protection and disaster management is a neglected area, also due to the poor legal framework in this field. According to the Office, the decentralised civil protection and disaster management system of the country established by the Civil Protection and Disaster Risk Management Law led to an unclear division of responsibilities among the risk management institutions.[22]

3.3.1.2 Comprehensive disaster risk reduction and climate change adaptation strategies

Latvia does not have a Disaster Risk Reduction Strategy[23]. Disaster risk reduction is incorporated within the National Civil Protection Plan (NCPP), which was adopted in August 2020 and replaced the previous plan dated 2011. The NCPP provides preventive, preparedness, response and mitigation measures related to national and regional disasters or threats of disaster. It determines the operation of the civil protection system in the event of a military invasion or war and supports the national defence system.

Latvia's climate policy is based on international agreements, such as the UNFCCC and the Kyoto Protocol (Doha amendment), the Paris Agreement and the main common EU policies. Climate change adaptation is actively integrated into sectoral policies, plans and programs. Latvia's Climate Change Adaptation Plan for 2030 (NAP 2030) as adopted by Order of the Cabinet of Ministers No. 380 on 17 July 2019. The overall climate change adaptation priority of Latvia is to reduce the vulnerability of people, economy, infrastructure, construction and environment to the impacts of climate change. To meet this aim, more than 80 concrete adaptation measures and 5 strategic goals to address climate change risks were developed.[18]

Other key cross-sectoral policy documents implementing the EU climate policy and targets, include the following strategies: "Sustainable Development Strategy for Latvia until 2030" (2010); "National Development Plan 2021- 2027" (2022); "National energy and climate plan 2021-2030" (2020); and "Strategy of Latvia for the Achievement of Climate Neutrality by 2050" (2020). In particular, Latvia's climate policy is defined in the framework policy document "Environmental Policy Strategy 2021-2027", which ensures Latvia's progress towards achieving climate neutrality, and promotes climate resilience and adaptation to climate change.[18]

3.3.1.3 Institutional Framework

According to the Civil Protection and Disaster Management Law, the Prime Minister is responsible for the functioning of the civil protection and crisis management system, while the State Fire and

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Rescue Service of Latvia, which is subordinate to the Ministry of Interior, manages, coordinates and controls the operation of the system and civil emergency planning.[21]

According to national legislation, vertical cooperation in disaster risk management is organised at three levels, namely the state, local, and onsite levels. The Crisis Management Council, led by the Prime Minister, coordinates civil-military cooperation and the operational measures of state administrative institutions to ensure a rapid response as well as a unified implementation of political decisions.[24]

While at the regional level crisis management structures do not exist, at the local level governments established and manage civil protection commissions, for a total of 38 civil protection commissions responsible for the coordination of civil protection measures in the event of disasters (or potential threats) in their administrative territories. The chairperson of the local government council manages the implementation of the civil protection and disaster management tasks at the local level. At the sectoral level, disaster management tasks are carried out based on the competences prescribed in the national legislation. Each risk management authority, in the field of its responsibility, carries out risk assessment, determines preventive, preparedness, response measures, and draws up planning documents, laws and regulations in line with their field of competence.[24]

Disaster management is coordinated in close cooperation by the Ministry of the Interior, the Ministry of Defence, the Ministry of Foreign Affairs, the Ministry of Economics, the Ministry of Environmental Protection and Regional Development (MEPRD), the Ministry of Transport, the Ministry of Health, the Ministry of Agriculture and local governments.[24]

The Ministry of Climate and Energy (MCE) has overall responsibility for national climate policy and compliance with the EU and UNFCCC requirements. Institutions supervised by the MEPRD – State Environmental Service, Environment State Bureau, as well as state LLC Latvian Environmental Investment Fund – and the Latvian Environment, Geology and Meteorology Centre (LEGMC) (subordinate to the MCE) ensure implementation of the climate policy within their competences. Other ministries involved in issues related to the development and implementation of the climate change policy include the Ministry of Finance, Ministry of Economics, Ministry of Transport, Ministry of Agriculture, and Ministry of Education and Science, as well as the institutions supervised by these ministries. Additionally, the Ministry of Interior, Ministry of Health, and the Ministry of Welfare have important roles in the implementation of climate adaptation policy.[18]

3.3.1.4 Coordination and partnership

Disaster management is internally coordinated by ministries and local governments, in close cooperation with relevant stakeholders, such as research institutes, NGOs and commercial companies. The MCE is responsible for the preparation and implementation of climate change adaptation measures. Two working groups, an intergovernmental group and an expert working group, work in coordination on tasks relating to climate adaptation and planning. The aim is to

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implement and coordinate multi-level cooperation involving the various sectoral stakeholders and ministerial institutions.[24]

Twenty-four Latvian local governments signed the EU Covenant of Mayors for Climate & Energy initiative. At the national level, the Department of Climate Change of the MCE has a coordination role within the framework of the Covenant of Mayors; at the same time, the department works closely with the Latvian Association of Municipalities. At the local level, administrations, such as municipalities, are involved in the development of civil protection and emergency planning, building and infrastructure, biodiversity and ecosystem services, and agriculture, fisheries and forestry.[25]

In the international context, Latvia takes part in the United Nations Sendai Framework for Disaster Risk Reduction, the Union Civil Protection Mechanism (UCPM) and in the macro-regional cooperation framework in the field of civil protection and disaster management at The Council for Baltic Sea States (CBSS), the inter-governmental political forum for cooperation in the Baltic Sea Region. Despite Latvia participating in the United Nations Sendai Framework for Disaster Risk Reduction, it has not developed a National Platform for Disaster Risk Reduction.

Transboundary cooperation operates through common projects between states: Latvia takes active part in the implementation of the EU Strategy for the Baltic Sea Region (EUSBSR, 2009) and is a member of the Baltic Sea Region Climate Dialogue Platform. The Baltic Sea Region Climate Change Adaptation Strategy and its action plan cover issues related to ever stronger rainfall and urban planning and provides practical solutions. The Baltic Sea Region Climate Dialogue Platform has the ambition to facilitate knowledge exchange of best practices and information on policy development in Baltic Sea Region countries, it fosters synergies among existing initiatives and identifies further cooperation opportunities.[26]

In the context of European cooperation, the CASCADE project has the main objective of increasing the practical risk management capacities of local authorities in the Baltic Sea Region and improving urban resilience in cities and towns as well as macro-regional resilience overall. Furthermore, CASCADE initiates a region-wide policy dialogue on the UN Sendai Framework for Disaster Risk Reduction as an effective platform for cross-sectorial cooperation between different levels of governance and for greater policy coherence on climate risk assessments.

The Environmental Protection Law together with the National Operational Programme “Growth and Employment” of EU Funds define education for sustainable development and environmental education by anchoring climate change in education and public awareness policies and practices that are continuously developed.[18]

3.3.1.5 Disaster Risk Financing

At the national level, financial resources for the implementation of civil protection activities are allocated by the State budget, while at the local level, they are financed by budgets of local

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administrations. State institutions and local governments in charge of response and recovery activities must allocate financial resources for their implementation within their own budgets. In the aftermath of a disaster, additional funds may be allocated by the government through a separate fund called "Funds for Unforeseen Events" and provided to state institutions and local governments upon request. Similarly, central and local authorities allocate funds from their budget for prevention and preparedness measures and include them in sectoral planning documents. When the allocated financial resources for the implementation of specific measures are not sufficient, the responsible ministry may request additional funds from the state budget or look for other sources of funding. Finally, the state budget is divided into specialised programs split among ministry sectors; while the financial allocations are provided for development purposes, the maintenance costs are incorporated into the annual budget as basic expenditure.[24]

As for risk assessment, there are no specific financial allocations at the central level. Ministries who are responsible for the coordination of disaster management measures of specific risks ensure the financial capacities to carry out risk assessment tasks in ad-hoc group meetings from their own budget. [24]

The NCPP has been developed considering the enabling conditions set out in Annex III of the Common Funds Regulation for the programming period 2021-2027. Investment condition number 5 requires the development of a national or regional disaster risk management plan at the national level, consistent with existing climate change adaptation strategies.[27]

3.3.1.6 Systemic Resilience

Latvia is generally well positioned in the systemic resilience index ranks of ND-GAIN, INFORM Risk, INFORM Climate and Human Development Index (HDI). The ND-GAIN Index, which combines a nation's vulnerability to climate change and other global threats with its preparedness to enhance resilience, ranks Latvia 35th out of 182 countries, being the 116th most vulnerable country and the 30th most ready one[28]. The INFORM Risk Index identifies countries at a high risk of humanitarian crisis using a model based on the three dimensions of risk (hazard & exposure, vulnerability and lack of coping capacity); it ranks Latvia as a very low risk country, 161st out of 191 countries[29]. The INFORM Climate Change positions Latvia among the top 10 countries with lower climate-related risk. Finally, the Human Development Index (HDI) ranks Latvia 39th out of 191 countries, positioning it in the Very High human development category.[30]

3.3.2 Risk assessment

3.3.2.1 Legislative framework and processes

In Latvia, the risk assessment process is regulated by the Civil Protection and Disaster Management Law (Law No. 100, 5672/2016), which identifies three main stages in line with the ISO 31000 standards: risk identification, risk analysis, and risk evaluation. Risk assessments at the different territorial levels are developed according to the competence, expertise and responsibilities of the

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national and local governmental authorities. Specifically, risk management authorities implement risk assessments for the hazards under their area of competence/responsibility, following the recommendations developed by the State Fire and Rescue Service - "Recommendations for Disaster Risk Assessment". These guidelines describe the criteria, process and methods to conduct comparable and consistent risk assessments by applying a unified approach.[27]

Latvia's national risk assessment is embedded in the NCPP, adopted in 2020 and drafted by the State Fire and Rescue Service. The NCPP is revised annually by the Ministry of the Interior and includes the risk assessments submitted by the risk management authorities, in cooperation with their subordinate institutions and experts. The national risk assessment analyses and evaluates 35 key risks (including climate-related risks) that should be considered by the national and local authorities in their risk management planning processes, while identifying prevention, preparedness, response, recovery and mitigation measures, also included in the plan. The NCPP is at the basis of local civil protection plans, developed by Municipal Civil Protection Commissions.[27]

The assessment of climate-related risks and their impacts is thoroughly addressed in the NAP 2030. The NAP 2030 focuses on climate change impacts in specific economic sectors of the country and identifies more than 80 concrete measures to facilitate adaptation both for the population and the Latvian economy.

Both the NCPP and the NAP 2030 are based on six sectoral risk and vulnerability assessments carried out by a groups of experts[g] under the macro-regional project "Development of a proposal for the National Climate Change Adaptation Strategy, identifying scientific data and measures for ensuring adaptation to climate change, as well as carrying out impact and cost assessment", funded by EEA and Norway Grants (2009-2014) - hereinafter "EEA project".[h] Indeed, the NCPP is aligned and harmonised with the NAP 2030 and the measures included in both documents are planned to be implemented in synergy and full coordination.[24]

The research and academia sector is engaged in and contributes to the risk assessment process. In particular, the Latvian Environment, Geology and Meteorology Centre (LEGMC) is the national institute responsible for developing climate monitoring and modelling systems, projections and scenarios. In cooperation with the MCE, the LEGMC is responsible for managing and running the Latvian Climate Change Monitoring System, which analyses climate change impact indicators in different economic sectors and collects data on their adaptive capacity, in accordance with the

[g] The group included experts from the Ministry of Environmental Protection and Regional Development; SIA "Baltkonsults"; SIA "Estonian Latvian & Lithuanian Environment"; SIA "Procesu analisis i prủvės centrs"; LVMI "Silava"; and the association "Zaļa Brīvība".

[h] Each annex of the NCPP in which climate change is addressed reports the NAP 2030 and the sectoral risk and vulnerability assessments.

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Regulation of the Cabinet of Ministers No. 675. The system includes regular monitoring of climate data and indicators. The LEGMC ensures that climate change scenarios are updated according to the latest IPCC scientific results.[31] The LEGMC also contributed to the drafting of the NAP 2030.

3.3.2.2 Risk identification

The NCPP is composed of the risk assessments submitted by the institutions and authorities responsible for disaster risk management, in cooperation with their subordinate institutions and experts. All risks identified within the plan shall be considered key risks.

In the NCPP, climate change is addressed in the contexts of the following risks: floods and windstorms; torrential rain, persistent rain, thunderstorms and hail, snow and blizzards, icing and sleet, severe frost, heat, drought; storms, tornadoes and strong wind gusts; forest and peat bog fires.[i] Additionally, risks that might be induced by climate change impacts are also addressed, such as landslides, epidemics/pandemic, epizootics, epiphytotic and interruption of critical services.

While the cross-border dimension is not integrated in the assessment, the NCPP considers floods, forest fires, storms, extreme weather affecting societal (critical) infrastructure function, and diseases (pandemic flu) as key risks that could have adverse cross-border impacts.

During the EEA project, experts from six different fields (see note g) identified the main risks and impacts of climate change relating to the following sectors: construction and infrastructure planning; civil protection and disaster management; health and well-being; biodiversity and ecosystem services; agriculture and forestry; and tourism and landscape planning. For each sector, a report on the risks and vulnerabilities of the research area was drafted and published on the website of the MEPRD.

The risk assessments developed within the EEA project and presented in the six reports are reported in a more synthetic form in the NAP 2030. In the plan, the climate-related risks with the highest probability of occurrence are presented as follows: “changes in seasons, including the growing season”; “fires”; “pest and pathogen outbreaks, tree diseases, displacement of native species, introduction of new species”; “spread of respiratory diseases”; “infectious diseases, heat strokes”; “flooding caused by rainfall, wind-driven flooding”; “power supply disturbances”; “increase in runoff, hydropower fluctuations”; “reduction of frost, frost, desiccation”; “eutrophication”; “damage to infrastructure, overheating of equipment”; “reduction of water runoff in the summer season”.

[i] This division of hazards follows the one provided in the NCPP, where they are grouped and presented in this form in the annexes of the document.

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3.3.2.3 Risk analysis

The risk matrix below (Figure 2) represents the outcome of the risk analysis included in the NCPP[j] and combines the level of probability, impact/consequence and risk level on a scale from 1 to 5 - probability ranges from very low to very high; risk from insignificant to very-high; consequence/impact from insignificant to catastrophic.

Level of probability ↓	DISASTER RISK ASSESSMENT				
	INSIGNIFICANT RISK	SIGNIFICANT RISK	MODERATE RISK	HIGHT RISK	VERY HIGHT RISK
VERY HIGHT		Forest fires and peat / turf fires	Epizootics		
HIGHT			Fluvial floods, floods Extreme heat / heatwaves Icing (snow storms)	Epidemic (influenza)	
MODERATE	Major vehicle accident	Damaged / damage to the transmission electricity network Major railroad accident	Strong frost Heavy and / or prolonged rainfall Thunderstorm and hail Whirlwinds Drought	Storm surge (coastal) Major disruption or damages to power network Storm Building fires	
LOW		Epiphytotic	Collapse of buildings Emergency of or gas leak from major transmission pipeline Passenger ship accidents Accident and/or spill of dangerous chemical substances Wet snow sediment		Damage/distruption of hydroelectric power plant - Daugavas HES Marine accidents with release of hazardous chemicals
VERY LOW	Landslides Earthquake Public disorder	Terror attack Internal unrest (conflict) Radiological accident Ship grounding accident	Emergency in oil product pipeline or its trasnsporting infrastructure Damage to the port or sea engineering infrastructure Collision of ship	Incidents or accidents with release of biological substance Major aviation accidents	
Level of consequence of impact →	INSIGNIFICANT IMPACT	SIGNIFICANT IMPACT	MODERATE IMPACT	HIGHT IMPACT	VERY HIGHT IMPACT

Figure 2: Outcomes of the risk analysis included in the NCPP. Source: Summary Report 2020

In the NCPP, each annex is dedicated to one or more threats and includes a description of risk scenarios, judgements on the probability and consequences of events and visual images.

In the context of climate change, climate extremes are considered from the following aspects: whether the frequency of their occurrence has increased compared to an earlier period; whether their intensity has increased compared to the earlier period; whether the duration of the

[j] Not all the risks included in the risk matrix (figure 2) are climate-related risks.

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corresponding phenomena is longer than the norm (previous time period); and whether they occur earlier or later according to the seasonal pattern.

Latvia's NAP 2030 presents the assessment of climate impacts, vulnerabilities and risks. It is developed on climate change analysis of the time periods 1961-2010 and projections up to 2100. The analysis of the past climate is based on historical data of all meteorological observation stations of the LEGMC, while future scenarios were developed using the projections of 28 global numerical climate models according to the GHG emission scenarios RCP4.5 and RCP8.5 of the IPCC 5th Assessment Report. Considering these past and future periods, trends in climate indicators (air temperature, rainfall precipitation, wind speed, sea and river water level, extreme weather events) are identified.

Results of the EEA project can also be found in the report "Climate change scenarios for Latvia", which discusses the past trends of change in climate variables and indicators, and the corresponding changes according to specific future climate change scenarios. Based on the RCP 4.5 and RCP 8.5, multiple climate models are adapted to the country by bias correction and statistical downscaling methods and compared to the latest climate change monitoring results. This information is available on the website of the Climate Change Analysis Tool (implemented within the same project) in the form of maps and graphs. These show 30-year average values for selected climatic parameters (air temperature; atmospheric precipitation; wind speed; snow cover) at the national level, and they can be explored in the tool by selecting future periods (2011-2040; 2041-2070; 2071-2100) and climate change scenarios (RCP 4.5 or RCP 8.5). At the moment, Latvia is working on the development of future climate change scenarios based on the Shared Socioeconomic Pathways (SSP) scenarios from IPCC 6th Assessment Report.[18]

Following the report "Climate change scenarios for Latvia", the LEGMC published further studies focused on past and future changes of parameters that were not covered within the report. These include studies on heat waves duration to date and projections for future scenarios (2017); snow cover thickness change scenarios for Latvia (2018); past and future periods of drought and wetness in Latvia, using the Standardised Precipitation Index (SPI) (2019); and changes in wind gusts to date and projections for future scenarios (2020).

In the 2018 report “Climate change monitoring systems description in Latvia'', the LEGMC provides a description of the Climate Change Monitoring System created within the EEA project. In the report, the climate change impact indicators developed are presented for each of the six sectors under consideration[k]. For example, in the sector related to civil protection and disaster management, one

[k] The indicators are: 6 indicators for landscape planning and tourism; 1 for biodiversity and ecosystem services; 5 for health and well-being; 9 for agriculture and forestry; 3 for civil protection and disaster management; 4 for construction and infrastructure planning.

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of the indicators considers the average area burnt per forest fire (ha); the number of hospitalisations for sunburn, heat and light exposure and unspecified fever per 100 000 population is one of the indicators identified for the health sector. For each impact indicator, the description, time period, the vulnerability calculation formula and other data are provided. In the Climate Portal of the LEGMC, a climate change impact database groups the indicators and vulnerability values covered in the report.

The six sectoral risk and vulnerability assessments developed within the EEA project address the most important climate related risks and benefits for the studied areas and analyse the vulnerability of each sector using qualitative and quantitative methods. In the risk analysis, which is based on scientific literature, data analysis and expert interviews, the authors of the six studies used a risk matrix approach based on the international standard Risk Assessment Techniques (ISO/IEC 31010:2009) and the SFRS report "Summary of risk assessment in Latvia".[32] The risk matrix approach is the same used in the NCPP (Figure 2). Always using a scale from 1 to 5, the vulnerability assessment - the vulnerability level ranging from very low to very high - is calculated by taking into account the risk level, (combining impacts/consequences with the level of probability); the economic losses; the adaptability of the system; and the size of the affected group. In some cases, such as in the health and well-being and the biodiversity sectors, other *criteria* are also considered, such as the Years of life lost (YLL) in the case of the health sector.

Based on all the information presented above, the NAP 2030 addresses the climate related risks (as shown in Figure 3) and underlines what are the possible negative consequences for each. Then, the risks with high or very high probability of occurrence and with the most negative consequences are specified. Thirdly, the most significant socio-economic impacts of climate change that may affect the related sector are described - in some cases, indirect impacts are also mentioned. A brief description of affected groups and economic losses is also provided.

Building and infrastructure planning:	Health and welfare:
Building • Increase in damages caused to buildings by flood along the seaside and river estuaries in cities • Increase in damage caused to buildings by precipitation flood • Increase in overload on the roof of buildings due to snow cover • Damages of the foundations of buildings and ground due to groundwater level fluctuations	• Increased spread of acute intestinal infections, outbreak of such infections • Increased spread of chronic diseases (CVD, diabetes, etc) and increased mortality • Increased spread of illnesses and/or infectious diseases caused by carriers of diseases become endemic • Increased morbidity and mortality rates caused by diseases of respiratory system in particular for various risk groups • Increased frequency of heat strokes • Internal migration, migration of foreign population to Latvia • Housing availability and provision

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• indoor overheating growth ***Transport infrastructure*** • Increase in damages caused to ports, roads by flood along the seaside and river estuaries in cities • Increase in damage on roads due to floods caused by heavy rainfall (along with road freezing period decrease) • Increased melting of asphalt and other road surface damages • Increased bending of rails, material deterioration and instability due to heat ***Energy*** • Electricity transmission and distribution network damages due to wind gusts • Indoor overheating and growth of electricity demand in summer • Energy demand decrease in winter	**Biodiversity and ecosystem services:** • Eutrophication of watercourses and water bodies • Ecologically sensitive species are taken over by ecologically plastic species • Spread of expansive and invasive foreign species non-characteristic to Latvia, infectious diseases and harmful organisms of plants • Opportunities for entry of new species • Increase in water temperature and longer stratification period, decrease in the amount of dissolved oxygen at the ground layers • Storm surges along the coastline, rising water levels in rivers and lakes
Tourism and landscape planning: • Risk of changing the length and characteristics of winter tourism season • Flood risk (rising water levels in rivers and lakes) • Coastal flooding and erosion risk along the coastline of the Balic Sea and the Gulf of Riga • Risk of the change of the length of the summer tourism season **Civil protection and disaster management planning:** • Flooding and ice buildup • Flood caused by heavy rainfalls • Storms and wind surges at the sea • Forest and peat fires	**Agriculture, Forestry and Fishery:** ***Agriculture*** • Destruction of crop fields, plantations due to black frost • Spread of crop diseases, harmful organisms (including new) and spread of pests, animal parasites (including new species) • Spread of previously non-characteristic disease agents and carriers, including spread of invasive foreign insect species • Drying and faster drying of soil/plants • Flooding of agricultural land under intense precipitation condition • Risk of long-term heat waves ***Forestry*** • Spread of tree diseases (including new) • Spread of tree pests (including new) • Risk of frost damage (including frost hardiness loss) • Hindered forest exploitation due to lack of winter freeze • Risk of storms • Risk of fire • Risk of tree damage due to freezing precipitation, windthrows and snow breaks • Faster drying of soil/plants ***Fishery*** • Increase in water temperature in water bodies, eutrophication • Ecologically sensitive species are taken over by ecologically plastic species • Opportunities for entry of new species (including invasive species) • Flood risk in open-type fish-breeding farms

Figure 3: Main climate change-related risks in Latvia (Latvian National Plan for Adaptation to Climate Change until 2030) Source: UNFCCC 2023

With reference to floods, risk assessments developed for the Flood Risk Management Plans (in accordance with the requirements of Directive 2007/60/EC of the European Parliament and the Council of October 23, 2007) have been considered in NAP 2030. The flood risk and hazard maps related to three different return periods are published on the LEGMC website.

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3.3.2.4 Risk evaluation

The Civil Protection and Disaster Management Law defines risk assessment as a process involving risk identification, risk analysis and risk evaluation. Nonetheless, it is not clear if the evaluation phase is carried out.[l] All the risks included in the NCPP are considered key risks, including those with low probability- low impact, such as landslides and earthquakes. Consequently, the risk management planning process covers all identified key risks, without taking into account their level of severity.

On the other hand, preventive and preparedness measures for each key risk are prioritised by applying a methodology which determines the priority/proportion of each risk by taking into account its potential economic impact. A risk assessed as "very high" in the risk matrix approach will have a potential economic impact of over €2 billion and a score value of 5, while the economic impact of a minor risk lies between €2 million to €6 million and has a score value of 1. The measure with the highest score values is considered a priority measure.[24 27]

3.3.2.5 Risk communication

Latvia does not have a strategy for communicating the results of risk assessments. However, national and local risk assessments are publicly accessible. The NCPP is available on the Latvian law portal, while local risk assessments are available on the official websites of municipalities or state cities. The six sectoral risk and vulnerability assessments developed in the context of the 2009-2014 EEA project are publicly available on the website of the MEPRD in the form of reports.

Risk scenarios and maps produced by the Climate Change Analysis Tool, managed by the LEGMC, are available on the website of the institution. In addition, the LEGMC provides flood risk information and maps as well as climate change information on social networks, regarding, for instance, climate monitoring, projections and advances in climate change research.[18]

The NCPP is published for public consultation on the website of the Ministry of the Interior, under the section "Public Participation", giving the general public and other entities the opportunity to participate in the development of the plan.[24]

3.3.2.6 Administrative, financial and technical capacities

As reported in the Summary Report, a few years ago an expert training showed that ministry experts were not sufficiently trained to conduct risk assessments in their field of responsibility; for this reason, some guidelines - the above-mentioned "Recommendations" - were developed by the States Fire and Rescue Service. Yet, the audit report of the State Audit Office highlighted some gaps in the risk assessment process. For instance, although the NCPP is available for public consultation

[l] The Civil Protection and Disaster Management Law defines risk evaluation ("risk assessment") as a "process during which the results of risk analysis are compared to risk criteria in order to determine whether the risk and the level thereof is acceptable or satisfactory".

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in the Ministry of Interior's website, it seems that public consultations have not taken place and that the public has not been informed about the risk assessment process and results.

3.4 Catalonia

Spain is a decentralised unitary state situated in the Iberian Peninsula and governed by a parliamentary monarchy. It comprises three levels of governance: the central level (the State), the regional level (composed of 17 autonomous communities and the two autonomous cities of Ceuta and Melilla) and the local level (provinces and municipalities). Autonomous communities exercise the right to self-government within the limits of the constitution and of their autonomous statutes.

Catalonia is an autonomous community situated on the northeast of Spain, bordering France and Andorra to the north, the Mediterranean Sea to the east, the autonomous community of Aragon to the West and Valencia to the south. It is administratively divided into 4 provinces and 947 municipalities, currently inhabited by a population of 7.899.056 people (2023).[33] The community's capital, Barcelona, is the second-most populated municipality in Spain. The official languages of Catalonia are three: Catalan, Spanish, and Occitan.

Despite having a relatively small area (32.000km²), Catalonia has a marked geographical diversity, consisting in three main geomorphic units: the Pyrenees on the northern side, the Catalan Coastal Mountain, alternating 580 km elevations and plans, and the Catalan Central Depression, part of the Valley of the Ebro.

3.4.1 Risk governance

3.4.1.1 Governance framework

The National Civil Protection System (NCPS) is governed by Law 17/2015 of 9 July 2007, which regulates the full civil protection cycle, from risk assessment to the recovery phase[34]. The NCPS is integrated into the National Security System and organised at three levels, in accordance with the territorial organisation of the State: the General State Administration, the Autonomous Communities and the Local Corporations.[35] The disaster risk management cycle (DRMC) is based on an inclusive approach to actions which emphasises the collaboration, cooperation, coordination, and equality between these three levels.[35]

Besides the Law on the National System of Civil Protection, the main regulatory instruments of the NCPS are: the Basic Civil Protection Standard (Royal Decree 407/1992); the Basic Self-Protection Standard (Royal Decree 393/2007); the National Civil Protection Strategy (Order PCI/488/2018); the Law on National Security (Law 36/2015 of 28 September); and the National Security Strategy (Royal Decree 1008/2017 of 1 December).[35]

In the Autonomous Community of Catalonia, the Catalan civil protection system is regulated by Law 4/1997. Decree 243/2007 on the structure of the Department of the Interior, Institutional Relations

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and Participation appoints the Directorate-General of Civil Protection of the Government of Catalonia as the body in charge of developing the civil protection system of Catalonia, its resources and associated structures and the devices necessary for its coordination.[36] [37]

In the field of climate change, the Catalan Parliament approved the Law 16/2017 on Climate Change, which adopts the bases derived from the EU legislation[38]. The law aims to reduce greenhouse gas emissions and promote the transition to an emission-neutral economy. Article 10 states that the competent department in the field of climate change must elaborate, jointly with the other departments and with the participation of the actors involved, the strategic framework of reference for adaptation, which must collect the evaluation of the impacts of climate change, in agreement with the knowledge state and the identification of the natural systems, the territories and most vulnerable socio-economic sectors.[39] Decree 573/2006 established the Catalan Office for Climate Change, which is the technical unit of the Government of Catalonia attached to the General Direction of Environmental Quality and Climate Change of the Secretary's Climate Action. The Office also acts as the technical and administrative support of the Interdepartmental Commission on Climate Change, whose functioning is defined by art. 30 of the Law on Climate Change.[40]

3.4.1.2 Comprehensive disaster risk reduction and climate change adaptation strategies

In the field of disaster risk reduction and climate change, the two main strategies at the national level are the National Civil Protection Strategy (2019) and the National Plan for Adaptation to Climate Change 2021-2030 (NAP 2020). National plans include risk-specific plans, energy and climate planning instruments and the General State Emergency Plan for Civil Protection (PLEGEM), which constitutes the top of the risk planning instruments, integrating all the state plans and the territorial plans of the Autonomous Communities.[35] In general, in accordance with the Basic Civil Protection Standard, the civil protection plans are: the General State Plan; Territorial Plans; Special Plans; and Self-protection Plans.

With regard to Catalonia, in 2012, the Government approved the first strategic document on climate change adaptation, the Catalan Strategy for Adapting to Climate Change 2013-2020 (ESCACC20). On 17th January 2023, the new Catalan Strategy for Adapting to Climate Change 2030 (ESCACC30) was approved. Its main objective is to improve adaptation to climate change in Catalonia and reduce its vulnerability through the establishment of 76 operational objectives and 312 adaptation measures.[41]

Relevant plans in the field of disaster risk reduction and climate change in Catalonia are: the Catalan Territorial Civil Protection Plan (PROCICAT), which is the main planning instrument that manages risks or emergencies not included in other special plans and is complementary to these; the Energy and Climate Change Plan 2012-2020; the Special flooding hazard emergency plan (INUNCAT); the Special snow hazard emergency plan (NEUCAT); the Special forest fire hazard emergency plan (INFOCAT); the Special avalanche hazard emergency plan (ALLAUCAT); Special plan for aeronautical

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emergencies (AEROCAT); Special plan for marine water pollution (CAMCAT); Special emergency plan for pandemics; Special external emergency plans for the chemical sector (PLASEQCAT; PLASEQTA); Special plan for radiological emergencies (RADCAT); Special plan for the seismic risk (SISMICAT); Special plan for the wind risk (VENTCAT); and Special emergency plan for accidents in the transport of dangerous goods by road and rail (TRANSCAT)[m].[42]

At the municipal level, the municipalities of Catalonia may be obliged or recommended to elaborate a Municipal Action Plan for the hazards identified within their territories, as reported in the Descriptive Report on the Civil Protection Map of Catalonia. The same report includes the municipal planning criteria, developed according to the above-mentioned emergency plans in force in Catalonia.[36]

3.4.1.3 Institutional Framework

The organisational structure of the NCPS is established at three levels: State, Autonomous Community, and local level. Each level has its own civil protection structure for the performance of the functions that fall within its remits.[35] The three levels act according to the principles of solidarity, complementarity and subsidiarity;[43] they have full competence for the development of all phases of the civil protection emergency cycle, while ensuring the cohesion of the system as a whole.[35]

The State is responsible for tasks relating to international relations, the basic rules of the System, the management of emergencies of national interest, support for other public administrations where they require extraordinary means, and general coordination of the system, which is organised through two bodies: The Ministry of the Interior, as an executive body, and the National Council for Civil Protection, as a coordinating body between the various public administrations.[35] The Autonomous Communities direct and coordinate civil protection activities within their territories, as referred to in their corresponding Civil Protection Emergency Plans and are responsible for all emergencies that are not of national interest.[35]

In Catalonia, the civil protection system is composed of the public services, including emergency services and technical services responsible for specific risks, such as the Meteorological Service of Catalonia; the self-protection services, which are responsible for activities and facilities, public or private, that may cause or suffer a serious emergency; and civil protection volunteering, integrated at the municipal level.[37] In accordance with Art.55 of Decree 243/2007, the Directorate-General of Civil Protection of the Government of Catalonia is in charge of managing the Catalan civil protection system and of organising, coordinating, and supervising the Operational Coordination Centre of Catalonia (CECAT), which is situated within the Interior Department.[44] The CECAT, established by Decree 246/1992, is the central coordinating and informational body for civil protection in Catalonia

[m] In general, all plans provide for their integration into higher-level areas, in order to ensure the cohesion of the entire NCPS and to facilitate the escalation of situations of interest to civil protection.

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and is responsible for the implementation, coordination and activation of the PROCICAT.[45] The Civil Protection Commission of Catalonia (Decree 291/1999) is the collegiate body of consultative, deliberative, coordinator and senior approver in the matter in Catalonia. It is composed of representatives of the Administration of the Government of Catalonia, the State Administration in Catalonia and the Local administration of Catalonia, which are responsible, among other things, of participating in the coordination of the activities of civil protection bodies and approving civil protection plans at the municipal and supramunicipal levels.[46]

At the level of the municipalities of Catalonia, the Municipal Operational Coordination Centres (CECOPAL) is, in a sense, the counterpart of the CECAT. The CECOPAL supports, at the municipal scale, the actions identified by the PROCICAT. The two Centres are constantly coordinated.[47]

In the field of climate change, the Interdepartmental Commission on Climate Change coordinates the actions of the ministries of Catalonia in the fight against climate change.[38] It is administratively and technically supported by the Catalan Office for Climate Change, which is responsible for promoting the establishment of climate change strategies, plans and projects in Catalonia. The Office is composed of two divisions, one dealing with adaptation and the other with mitigation issues.[40] Other bodies are the Climate Change Social Roundtable (see next section), and the Committee of Experts on Climate Change. The latter is a collegiate body affiliated with the ministry for climate change composed of seven members named among academic and professional experts of renowned prestige in fields related to the functions of the Committee. It is responsible for presenting proposals of carbon budgets for the different time periods, monitoring and assessment to Government and to Parliament.[38]

3.4.1.4 Coordination and partnership

The NCPS is funded on principles such as the coordination, cooperation, and subsidiarity between the General State Administration, the Autonomous Communities and the local authorities, throughout the entire DRMC. Spain's DRR National Platform consists of the National Commission for Civil Protection, which is an inter ministerial institution dependent on the Ministry of Interior and coordinated by the Directorate General for Civil Protection. It is composed of representatives from all the different political subdivisions and levels of administration, including the Autonomous Communities. Its mandate includes, among other activities, the promotion of the participation and coordination of different public administrations, private entities and specialised personnel in international cooperation projects related to disaster prevention and mitigation.[48]

At the regional and municipal level, coordination in the field of disaster risk management is ensured by the CECAT and the CECOPAL, while at the national level, vertical coordination is carried out by several bodies, including: the National Centre for Emergencies (CENEM) which coordinates response from the State when major events occur; the State Coordination and Management Committee (CECOD), which is one of the governing bodies of the PLEGEM responsible for coordinating the

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participation and actions of the public administrations and bodies involved in the management of emergencies under the PLEGEM (including competent bodies of the Autonomous Communities); the National Interconnection Plan, which ensures coordination between the essential organisations of the National civil protection system, including the Emergency Services in all Autonomous Communities; and the National Alert Network (RAN), a warning system to inform the competent civil protection authorities during an emergency.[49] In case of emergency at the level of the Autonomous Communities, the civil protection will intervene upon confirmation by the National Council for Civil Protection that the emergency is not of national interest.[35]

In accordance with Art.31 of the Law on Climate Change, the Climate Change Social Roundtable, a collegiate body affiliated with the ministry responsible for climate change, is responsible for channelling participation, information and consultation to the most representative institutions and organisations in the social, economic and environmental fabric of Catalonia on climate policies. Art.33 promotes, through current collaboration and cooperation mechanisms and bodies, the participation of local authorities both in climate policy planning and in sectoral action plans.[38] Furthermore, local authorities of Catalonia are part of the Covenant of Mayors for Climate and Energy promoted by the European Commissions, as well as of other networks and tools dealing with the fight against climate change.[50]

An example of collaboration with the general public is the participation process organised by Catalan Office for Climate change during the drafting of the operational objectives and the adaptation measures of the ESCACC30.[41] 740 proposals were submitted by the public.[39]

3.4.1.5 Disaster Risk Financing

All civil protection activities, in their various territorial areas, are financed through the corresponding General Budget.[35] The National Emergency Prevention Fund, regulated by Art.11 of the Law on the NCPS, is a financial instrument aimed at giving the necessary impetus to actions for the analysis and location of risks, awareness campaigns and information campaigns, preventive measures for the citizens, education programmes for prevention in schools or other similar programmes, with a view to concluding agreements between the General Administration of the State, the Autonomous Communities and the other public and private entities.[34]

As of Catalonia, all civil protection activities are financed through the General Budget of Catalonia, as occurs in the other Autonomous Communities.[35] In the field of climate change, the Climate Fund (regulated by Art.55 of the Law on Climate Change) implements mitigation and climate change adaptation policies and actions; it is a public fund, without legal personality, affiliated with the ministry responsible for climate change.

Catalonia is also a signatory of the EU Mission for Adaptation to Climate Change

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3.4.1.6 Systemic Resilience

In November 2014, the Catalan Office for Climate Change published the report "Global Indicator of Adaptation to the Impacts of Climate Change in Catalonia", which introduced a new global indicator of adaptation that allows to monitor the evolution of Catalonia's adaptive capacity to the impacts of climate change.[51] The report was updated in 2018 in order to respond to one of the generic measures provided for in the ESCACC20, namely the establishment of a monitoring system and indicators of the planned adaptation measures with the aim of evaluating whether adaptation to the impacts of climate change evolves favourably.

3.4.2 Risk assessment

3.4.2.1 Legislative framework and processes

In Spain, Autonomous Communities are responsible for risk assessment.[35]

In Catalonia, article 12 of the Law on the Catalan Civil Protection System and the Decree on the structure of the Department of the Interior, Institutional Relations and Participation state that the Directorate General of Civil Protection must prepare and regularly revise the Civil Protection Map of Catalonia. The Map is a cartographic tool that presents georeferenced risk information and shows the different territorial areas of Catalonia affected by hazards; it is created based on information and studies of the competent bodies in the administrations for each hazard. The Descriptive Report of the Map includes the description of the risk identification and analysis methodologies used for assessing each of the risks shown in the Map;[52] collective risks with effects in the mid and long-term, including climate change, are considered. Nonetheless, the only available version of the Descriptive Report dates back to 2010, and it is not clear whether this version is the last published.

On the other hand, risk assessment is also carried out for the risks addressed in the special plans.[n] Special plans - which may be state or regional plans - are drawn up in accordance with the Basic Civil Protection Standard, approved by Royal Decree 524/2023 and defined by Article 13 of Law on the National Civil Protection System (Law 17/2015). The Basic Standard establishes the basic guidelines for the identification of emergency risks and actions for their integral management as well as the Basic Planning Guidelines to be followed in the drafting phase of the planning documents. Among other things, the description of the risk analysis methodology adopted has to be included in the final official documents. In Catalonia, risk assessment was carried out for the following (natural) risks, in the context of their special plans: avalanche (ALLAUCAT), floods (INUNCAT), snowfall (NEUCAT), seismic risk (SISMICAT), forest fire (INFOCAT), and wind (VENTCAT).[42] As reported in Art.43 of the

[n] The annex of the Basic Standard presents the catalogue of risks that must be the object of planning (and, thus, of risk assessment). However, each administration may include in its civil protection plans risks that do not appear in the catalogue according to the particularities of each territory.

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Law on the Civil Protection of Catalonia, special plans are drafted by the Government's Counselor, which is the main authority of the Catalan civil protection.[46]

Risk assessment specific to climate change-related risks was carried out in the context of the ESCACC30 (Catalan Strategy for Adapting to Climate Change) and is included in an Annex of the official document, named "Impact and vulnerability in natural systems, socio-economic areas and territories" (hereinafter "Impact and vulnerability assessment"). The approach used in the impact and vulnerability assessment report consists of a collection of the latest scientific knowledge on risk assessment derived from projects and relevant studies and reports, including the above-mentioned special plans. This shows the alignment of the ESCACC30 with the special plans and the Descriptive Report of the Map for Civil Protection - the Descriptive Report reports the risk analysis methodologies used in each Special Plan for each of the risks addressed.

3.4.2.2 Risk Identification

Although the special plans provide an extensive description of the risk analysis methodology adopted in relation to their risk, climate change is not directly considered or mentioned in these documents.

Contrarily, climate change is the main object of the Impact and vulnerability assessment report. In the latter, climate hazards (see Table 1) are identified for each of the following systems and related sub-sectors of Catalonia (for which the impact and vulnerability assessment was carried out): *natural systems* (biodiversity; water; forest and forestry; marine ecosystems and fisheries); *socio-economic areas* (agriculture and livestock; insurance and financial sector; energy; industry; services and trade; mobility infrastructure; natural hazards and civil protection; research and training; health; tourism; urbanism and housing); and *territories* (inland; coastal; mountain).[53]

System	Sphere/sector	Climate hazard
Natural systems	*Biodiversity*	Increase in temperatures; and droughts
	Water	Increases in temperature; dry spells; evapotranspiration; and irregular precipitation
	Forests and forestry	Drought; Temperature increase and associated precipitation anomalies
	Marina ecosystems and fisheries	Rising sea temperatures; marine heatwaves
Socio-economic areas	*Agriculture and livestock farming*	Decreased cold hours in winter; Increasing temperature and decreasing precipitation; heatwaves
	Insurance and financial sector	Extreme weather events
	Energy	Drought and reduced water availability; extreme weather events; increased temperatures
	Industry, services and trade	Drought and reduced water availability; extreme weather events; higher temperatures

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	Mobility and port infrastructures	High temperatures; heavy rainfall; strong winds; sea level rise; extreme events and prolonged droughts; sea storms
	Natural hazards and civil protection	Floods; droughts; forest fires; geophysical risks
	Health	Heatwaves; Temperature increase
	Tourism	Sea level rise; higher temperatures
	Urban planning and housing	Temperature increase; extreme weather events; sea level rise; irregular rainfall
Territories	*Inland areas*	Temperature increase; increased dry spells with rainfalls below 1 mm; increased precipitation intensity; extreme weather events
	Coastal areas	Sea level rise; temperature increase; acidification; extreme sea storms
	Mountain	Increase in temperatures and droughts; Increase in extreme weather events

Table 1: Climate hazard per sector as identified in the Impact and vulnerability assessment report (ESCACC30). Source: Executive Summary ESCACC30

In the ESCACC30, a table summarising the identified climate hazards, impacts, exposure, vulnerability and risks for each sector is provided.

Collection of data

The analysis of the vulnerability of systems, areas and territories collects all the latest scientific knowledge on the subject and the experience acquired over the last few years in the development of adaptation policies. Specifically, account has been taken of the studies and reports commissioned by the Climate Change Office, in collaboration with other bodies of the Catalan Government[o], as well as of the background and results achieved in several European funded projects (projects in which the Catalan Climate Change Office participated; POCTEFA projects; Interreg projects; H2020 projects; projects of the Biodiversity Foundation)[p].[53]

In the ESCACC30 annex "Diagnosis of climate change in Catalonia", the analysis of the evolution of climatology in the Catalan Region is provided. The data analysed are distinguished with respect to the trend of climate variability in the past and the projections of future scenarios. Firstly, climatic variables, such as temperature, precipitation and sea level, are historically analysed. Furthermore, some climatic indices are collected with the aim of understanding the characterization of the

[o] Meteorological Service of Catalonia, Center for Ecological Research and Forestry Applications, Center of Forest Science and Technology of Catalonia, Catalan Water Agency, Center for Forest Property, Ports of the Generalitat, Cartographic and Geological Institute of Catalonia, Railways of the Generalitat of Catalonia, General Directorate of Road Infrastructures and others.

[p] Life MEDAC, Life Ebro Admiclim, Life Clinomics, Life Pletera, Life Climark, Life MIDMACC (Life project); Pyrenean Climate Change Observatory (OPCC) (POCTEFA project); Bewater, MPA-Engage (Interreg projects); Impetus (H2020 project); ISACC Tordera (Foundation project).

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region's climate.[54] The study of the evolution of the snow cover, the phenological observations and the surveys of extreme storm events and strong winds also contribute to the analysis of the past climate.

The same annex presents the conclusions of the latest-high resolution (1km) climate projections from 1971 to 2050, realised by the Meteorological Service of Catalonia (MSC) in collaboration with the Barcelona Supercomputing Centre. The climatic variables are projected for the periods 2021-2030 and 2021-2050 and compared to the reference period 1971-2000, according to the RCP 4.5 and RCP8.5 scenarios; the values are calculated starting from the 50th percentile of the variations simulated by the three globalized models, MPI-ESM (Germany); GFDL-ESM2G (USA); CanESM2 (Canadian).[54]

The Annual Bulletin of Climatic Indicators (BAIC) prepared by the Meteorological Service of Catalonia (MSC) provides indicators and statistical trends of the evolution of the recent climate in Catalonia from various perspectives, and captures the characteristics of climate variability (air temperature, precipitation, climate extremes, secular observatories, sea and phenology).

3.4.2.3 Risk Analysis

The risk assessment carried out for the ESCACC30 is based on the IPCC's Fifth Assessment Report, which defines risk as the result of the interaction between hazards arising from climate change (including extreme phenomena and changing trends) and the vulnerability and exposure of human and natural systems to these hazards.[53]

The Impact and vulnerability assessment report provides, for each sub-sector, the analysis methodology used in the projects, studies and detailed reports mentioned in the introduction of the ESCACC30 (see Risk Identification). The analysis is centred on the impacts and vulnerabilities of the Catalan systems, areas and territories to climate change.[55] Based on the results of the projects and studies, changes in the climate system and in the socio-economic processes are analysed and considered as the central drivers determining the hazards, exposure and vulnerability. The only part in which the analysis is risk-focused is the “natural risk and civil protection” sub-section (under the system “socio-economic field”). In the latter, the risk of floods, droughts, forest fires, and geophysical risks were analysed as follows:

- **Floods:** The risk associated with floods are analysed on the basis of the INUNCAT special plan and according to the data of the 2023 Flood Prevention Campaign.[56] The flood risk is estimated considering the vulnerability - estimate of the population affected; estimate of the kilometres of the road network; economic evaluation of the losses - and the hazard of the different types of rain warnings issued by the SMC. The result is a dynamic flood risk map indicating the most

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vulnerable and at-risk municipalities[q]. The future effects of climate change on flooding have been analysed by the Catalan Water Agency through the analysis of the potential influence of climate change on two components determining the variation and frequency of the laws of flow, namely the meteorological and the land use components.[57] The resulting maps, according to the return period (10, 100 and 500 years) and the GHG emission scenarios considered (RCP 4.5 and RCP 8.5), indicate the areas subject to probably significant and highly significant increases of influence of climate change. In the INUNCAT, a risk level scale ranging from low to very high describes the risk level of each municipality. A total of 21 municipalities significantly affected by rain or river floods and 5 by coastal floods were identified through the analysis of past events.[55]

- **Droughts:** In Catalonia, the pluviometric drought is analysed through the historical records of the Standard Precipitation Index (IPE), which allows an assessment of the deficit or excess of precipitation in the territory for different aggregation times. The high-resolution climate projections of the SMC are used to estimate annual and seasonal rainfall anomalies for both the coastal/pre-coastal area and the interior of the country.[55]
- **Forest fires:** In Catalonia, the Special emergency plan for forest fires (INFOCAT) analyses the wildfire hazard and assesses the vulnerability of following elements: population, particularly dangerous elements, infrastructure, protected natural areas, and fuel models. The fire risk is vaguely assessed according to the hazard determination scheme, the vulnerability analysis of the above-mentioned elements, and the exposure of the elements vulnerable to the hazard. In the INFOCAT, a map of the Catalan zones affected by the fire hazard is provided along with a hazard scale ranging from law to very high level.[58]
- **Geophysical (landslides/avalanches):** Geological risks in relation to climate change are not directly assessed in ESCACC30, but their relevance is recognized within the document "Storm Gloria (19-23/01/2020): The effects of geological processes on the territory", which offers a comprehensive sample of the collection of damages produced by the storm generated by fluvial, coastal and slope dynamics, or by their combination.

3.4.2.4 Risk Evaluation

It is not clear whether the risk evaluation phase, based on the results of risk analysis, was carried out for the above-mentioned risks. However, it might be argued that the most significant risks affecting the territory of Catalonia are those for which special plans are drafted.

3.4.2.5 Risk communication

One of the main objectives of the Civil Protection Map of Catalonia is to provide the public administrations and the general public with an overview of the hazards that could affect Catalonia.

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[q] The maps are reported as images at page 127 of the INUNCAT. Nonetheless, a link to the dynamic flood risks maps is not available in the document.

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The Map is considered a strategic tool that sets out a framework for the knowledge and dissemination of the hazards to the entire society.[36]

Planning documents in the field of disaster risk reduction - which include risk assessments - as well as reports, projects and planning documents in the field of climate change and climate change-related risks are available and accessible to the public through the official website of Catalonia.[59]

3.4.2.6 Administrative, financial and technical capacities

The administrative organisation of the country in the field of disaster risk reduction and climate change is built upon the principles of coordination and subsidiarity between the three levels of governance/civil protection. This results in a well-structured system of the Catalan civil protection which, among other functions, has full responsibility for risk assessment.

In the field of climate change, the ESCACC30 shows an all-embracing approach in relation to risk assessment which takes into consideration several studies, reports and projects that took place in Catalonia or in which the autonomous community participated. For instance, relevant planning documents in the field of disaster risk reduction (special plans) were largely considered and mentioned in the Impact and vulnerability assessment of the Strategy, proving the alignment of most relevant documents in this matter. However, the ESCACC30 highlights the need for civil protection plans (including the above-mentioned special plans) to incorporate the climate change emergency as a factor of change.

3.5 Setúbal

The Portuguese territory comprises the following three geographic areas: the mainland (located in the European Plateau), the Archipelagos of the Azores and the Archipelago of Madeira, which are two autonomous regions.

In administrative terms, the country is divided into three levels: districts (20), municipalities (308) and parishes (3092).[60] This administrative structure guarantees the principles of interdependence and separation of powers, as well as the principles of decentralisation and regional and local autonomy. Specifically, municipalities are ruled by an executive body (*Câmara Municipal*) presided by the mayor (*Presidente da Câmara Municipal*) and a deliberative body (*Assembleia Municipal*). Both bodies are directly elected.

Another type of administrative division divides Portugal into two metropolitan areas (Lisbon and Porto) and 21 intermunicipal communities.

Setúbal is a municipality in Portugal and is part of the Lisbon Metropolitan Area. It is situated in the Setúbal Peninsula, bordered by the estuary of the river Sado and the Sierra da Arrábida. In 2021, the municipality had a population of 123,496[61], and an area of 230.33 km^2. About 53% of the

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territory is part of a protected area, as three natural parks surround the city: the Parque Natural de Arrábida, the Parque Marino Luiz Saldanha, and the Reserva Natural do Estuário do Sado.[62]

3.5.1 Risk governance

3.5.1.1 Governance framework

Law n.27/2006 on Civil Protection regulates the activities of the Portuguese Civil Protection System at the national level. While in the past the Portuguese civil protection intervened only in the case of relief and emergency response issues, in recent times a big effort has been made to move towards the whole DRMC and strengthen the prevention aspect; this is also evidenced by the establishment of Portugal's National Civil Protection Prevention Strategy of 2017 and, consequently, of 2030.[r]

The wide range of legal bases regulating the Portuguese Civil Protection System lay the foundation of a multi-level system which has a strong focus on bottom-up activities. Specifically, at the local level, several laws have been approved to strengthen the powers and responsibilities of local civil protections[63], such as Decree-Law no.44/2019, which transfers the competences in the field of civil protection to municipal bodies. Law no.65/2007 regulates the Municipal Civil Protection System by defining its institutional and operational framework, establishing the organisation of the municipal civil protection services and determining the competences of the Municipal Operational Commander. Regulation n.147/2009 defines the composition and functioning of the Municipal Commission for Civil Protection. In this context, the main document in force is the Municipal Civil Protection Emergency Plan which provides general guidelines for the management of the risks that could impact the territory, including natural hazards and pandemics.

In the field of climate change, the Portuguese Climate Law (Law n.98/2021) establishes the reinforcement of sectoral, regional and local climate action plans. At the national level, the above-mentioned instruments converge into two main strategies for disaster risk management: the National Strategy for a Preventive Civil Protection and the National Strategy for Climate Change Adaptation (ENAAC 2020).[64]

3.5.1.2 Comprehensive disaster risk reduction and climate change adaptation strategies

The Setúbal Adaptation Strategy and its Action Plan was published in 2022 and developed within the framework of the project PLAAC-Arrábida (Local Adaptation Plans to Climate Change[65]), financed by the Environment, Climate Change and Low Carbon Economy Program of the EEA Grants Financial Mechanism 2014-2021. The PLAAC project takes the form of three local adaptation plans in the municipalities of Setúbal, Palmela and Sesimbra (namely, the Arrábida territory), in which adaptation measures to climate change will be defined and prioritised in the short, medium and

[r] The national instruments that deal with risk management and reduction converge into two main DRM strategies: the National Strategy for a Preventive Civil Protection and the National Strategy for Climate Change Adaptation.

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long term. The PLAAC is aligned with the vulnerabilities and measures identified in the ENAAC 2020 and the Action Program for Adaptation to Climate Change (P-3AC), and follows the methodological guidelines of the Metropolitan Climate Change Adaptation Plan of the Metropolitan Area of Lisbona (PMAAC-AML [66]).

The Municipal Plan for Adaptation to Climate Change is currently in the implementation phase. [67]

The Action Plan for Sustainable Energy in Setúbal (PAESS) (2014) is a key instrument to ensure compliance, at the local level, with the commitment to achieve and exceed the objective of reducing carbon dioxide emissions by 20 percent by 2020. Accompanying this action, the Action Plan for Energy and Climate Sustainability of Setúbal is being developed and will aim at restricting carbon dioxide emissions by 40 percent by 2030 and integrate the climate adaptation component[68]. Furthermore, since 2014, the municipality of Setúbal has taken part in the movement "Global Covenant of Mayors for Climate and Energy", which also contributes to a 40% reduction in CO2 emissions in the atmosphere by 2030.[69]

Other relevant plans with the aim to reduce and/or manage risks in the municipality include: the Municipal and Civil Protection Emergency Plan; the Municipal Forest Defense Plan against Fires; the Evacuation Plan of Setúbal; the Municipal Intervention Plan in the Historic Centre; the Municipal Plans for the Spatial Planning; and the Pluvial Drainage Plan in the Setúbal County.[70]

3.5.1.3 Institutional Framework

The Portuguese disaster risk management and civil protection system is a multi-level system, whose structure is organised at the national, regional, district, municipal and parish levels. It follows the subsidiarity principle which enables the close involvement of local communities and stakeholders.[63] At the national level, the Prime Minister and the Ministry of Internal Administration are responsible for civil protection. Under the Portuguese National Authority for Emergency and Civil Protection (ANEPC), the National Command for Emergency and Civil Protection controls and manages operations on an ongoing basis.[64]

At the municipal level, the mayor is responsible for civil protection, while the Municipal Civil Protection Commission is in charge of coordinating activities. Each municipality is also equipped with a Municipal Civil Protection Coordinator and a Municipal Civil Protection Service, which report to the mayor and are responsible for the prevention and assessment of risks and vulnerabilities, planning and support for operations, logistics, communications and public awareness raising. At the sub-municipal level, the parish leaders can establish Local Civil Protection Units to support municipalities in their civil protection activities.[64]

As for Setúbal, the Setúbal Municipal Civil Protection and Fire Service (SCPFS) is the municipal unit responsible for implementing the security policy of the territory within the scope of civil protection. It supports the mayor in carrying out civil protection activities and coordinating rescue and

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assistance actions in situations of serious accident, catastrophe or public calamity. In addition to the mayor and the SCPFS, the municipal civil protection system is also composed of the Municipal Civil Protection Commission, the Local Civil Protection Units, the Municipal Commission for the Defence of the Forest Against Fires.[71]

Finally, the municipality of Setúbal has a significant number of key entities relevant for climate adaptation actions at the municipal scale. These are listed in Annex I of the PLAAC's report 'Assessment of Current and Future Climate Impacts and Vulnerabilities in the Municipality of Setúbal' (hereinafter "Assessment Report") for each strategic sector of the Portuguese economy (the "ENAAC sectors" - see Risk Assessment). According to the Assessment Report, the ENAAC sectors are represented by public and private entities that have adequate resources, skills and capacities for climate adaptation in the municipality of Setúbal.[72]

3.5.1.4 Coordination and partnership

In 2010, Portugal established a National Platform for Disaster Risk Reduction, following the Sendai Framework for DRR.[73] The Platform involves over 50 governmental, non-governmental, private and scientific stakeholders, and aims at increasing resilience at the local level, regulating building assessments, building codes on seismic risks, implementing a disaster loss database and protecting cultural heritage.[63]

Following the publication of the Guidelines for building a local platform for DRR published by the ANEPC[74], Setúbal started to create a municipal platform for DRR[75]. The local platform will be a space for exchanges and increased local synergies, bridging the gaps between academia, technical reports, stakeholders' actions and the population. Both the national and the municipal platform follow the "Words into Action'' guidelines of UNDRR, developing strategies and implementing operational measures in the areas of leveraging partnerships, adopting a multi-hazard approach and customising approaches to fit the local context as well as sharing baseline knowledge of local disaster risk and resilience.[70]

In general, the horizontal coordination is managed by ANEPC at national and district level, while the Municipal Councils take on board the same responsibility at the local level. At the national, district and local levels, hubs for institutional coordination also foster horizontal coordination among civil protection authorities and a large group of public and private entities relevant to civil protection and relief. Additionally, the ANEPC is supported by an inter-ministerial Coordination Group, responsible for ensuring the coordination of the National Strategy with other sectoral instruments in the field of prevention and preparedness; this Group includes representatives from the areas of civil protection, from the National Association of Portuguese Municipalities and the National Association of Parishes.[64]

The engagement and collaboration between the civil societies, the private sector and local authorities have proven effective during the PLAAC project. For each of the three municipalities, a

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Local Climate Adaptation Network was established where 200 local agents, civil societies and the private sectors participated and contributed to laying down the adaptation measures.[76]

The Joint Research Centre of the European Commission has developed and installed in the municipality a prototype to test a future communication panel for tsunami warnings (SCHEMA Project[77]).

Setúbal is also a signatory of the EU Mission for Adaptation to Climate Change.

3.5.1.5 Disaster Risk Financing

Disaster risk funding at the municipal level depends on the civil protection budget. However, according to the Peer Review Report (2019), this system lacks a funding mechanism that ensures appropriate resources to equally implement civil protection activities across the municipalities, including equal target levels of safety and security.[63]

In the event of a disaster that affects the municipality, the "Municipal Emergency Fund" is activated by a resolution of the Council of Ministers. This fund is specifically addressed to municipalities, intermunicipal communities and metropolitan areas and aims to grant financial aid for the recovery of public equipment under their responsibility.

3.5.1.6 Systemic Resilience

At a national level, Portugal is generally well positioned in the systemic resilience index ranks of ND-GAIN, INFORM Risk, INFORM Climate and Human Development Index (HDI).

As for the Setúbal, in 2014, the municipality joined the UNDRR campaign "Making Cities Resilient – My City is Getting Ready" (2010-2020), together with other 35 Portuguese municipalities;[64,77] in 2021, it took part to the subsequent initiative "Making Cities Resilient 2030" with other 53 municipalities.[78] These campaigns aim to develop methodologies, programs, and actions capable of empowering the population, communities, institutions, companies and society's support systems to resist, survive, adapt and recover when faced with stress or disaster.

In this context, the ANEPC, supported by local partners from different sectors, has begun a process of monitoring aimed at testifying and highlighting the initiatives carried out, or still underway, by the Portuguese municipalities to reduce risks and promote their resilience in their territories. The report "Resilient Cities in Portugal -2018"[79] presents the good practices, the capabilities implemented and the results achieved by the Portuguese municipalities in this context.

3.5.2 Risk assessment

3.5.2.1 Legislative framework and processes

At the municipal level, risk assessment is one of the main tasks of the Municipal Civil Protection Service.[64] In Setúbal, the risk assessment is included in the Municipal Emergency and Civil Protection Plan, lastly updated in 2014. A more recent version, titled "Assessment and Cartography of Natural,

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Mixed and Technological Risks in the Municipality of Setúbal (ACNMTR)", was published in 2020 and is connected with the Municipal Master Plan[s] of Setúbal.[80]

In Setúbal, the assessment of climate-related risks was carried out within the framework of the PLAAC - Arrábida project. Published in 2022, the Assessment Report identifies climate impacts and vulnerabilities, current and future climate hazards and risks, and the priority territories of Setúbal at risk. The Assessment Report, and more in general the PLAAC project, was drafted in close cooperation between the Faculty of Science and Technology of Universidade Nova de Lisboa (FCT-NOVA), the Institute of Geography and Spatial Planning of the University of Lisbon (IGOT-ULisboa), the Energy and Environment Agency of Arrábida (ENA), and the municipality.

During a that took place in Setúbal in March 2023, the coordinator of the Municipal Civil Protection and Fire Service of Setúbal José Luís Bucho indicated that the Municipal Emergency and Civil Protection Plan is being revised also following the studies conducted within the PLAAC project.

3.5.2.2 Risk Identification

The risk assessment report of 2022 identifies seven climate events that were responsible for generating impacts on Setúbal: *low temperature weather events* were responsible for generating dangerous cold/snowfall processes; *dry hot weather events* caused heat waves and rural/forest fires; *precipitation scarcity* caused meteorological droughts; climatic events of *maritime agitation* were responsible for the occurrence of overtopping and coastal erosion; *strong wind weather events* were associated with strong wind/tornado; *intense precipitation* events triggered floods/floods and slope instability; and the last type of climatic event combines *intense precipitation with strong wind*. In the last two decades, 45 climate events with impacts were recorded in the municipality, with 16 events of intense precipitation and 13 events of precipitation scarcity.[72]

Climate events	Impacts	N.of climate events with impacts
Low temperature	Dangerous cold/snowfall processes	2
Dry hot weather	Heat waves and rural/forest fires	7
Precipitation scarcity	Meteorological droughts	13
Maritime agitation	Overtopping and coastal erosion	3
Strong wind	Strong wind/tornado	1
Intense precipitation	Floods/floods and slope instability	16
Heavy precipitation + strong wind	Floods/floods; slope instability and floods/ instability of slopes	6

[s] As part of the Municipal Master Plan (MMP), the Multi-Hazard Assessment map of the Municipality of Setúbal was created.

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Table 2: Number of climatic events with impacts as registered in the PIC database in the municipality of Setúbal (2000-2020). Source: PLAAC: "Assessment of current and future climate impacts and vulnerabilities in the municipality of Setúbal".

Chapter three of the Assessment Report identifies the following climate hazards with incidence in the municipality of Setúbal: rural/forest fires; slope instability; fluvial floods; estuarine floods; floods and coastal overtopping; coastal erosion and cliff retreat; excessive heat; drought; wind storms; soil water erosion.[72]

Collection of data

For the identification of climate impacts in the municipality of Setúbal, a systematic survey of information was carried out to identify the extreme weather events that affected the municipality in the period of 2000-2020. The survey was conducted by the technical services of the municipality, through research in reports and internal records of municipal services (in particular, the municipal civil protection service), municipal archives, local press articles published online, and in reports from the District Relief Operations Center and fire brigades. With regard to heat waves and droughts (not addressed by the aforementioned survey), the IGOT-ULisboa carried out bibliographic research of scientific articles; parallelly, the Portuguese Institute of the Sea and Atmosphere (IPMA) reports for the identification of hot and dry weather and precipitation scarcity in the last 20 years. The information collected was systematised by the IGOT-ULisboa team in Climate Impact Profile (CIP) database, developed based on the 'Local Climate Impact Profile' tool,[81] one of the resources made available by the UKCIP Adaptation Wizard (UK Climate Impact Programme) and adapted to the Portuguese reality within the ClimAdaPT.Local project.[72]

3.5.2.3 Risk Analysis

After a first chapter on the identification of current climate impacts, the Assessment report presents, in order: the sensitivity assessment of Setúbal's strategic sectors of the economy to climate impacts; the analysis of the adaptive capacities of the municipality; current climate hazards, accompanied by a susceptibility assessment; the analysis of the exposure to current and future climate hazards; future climate hazards; the analysis of current and future climate risks; and the priority risk territories.

The *assessment of the sensitivity* of Setúbal to climatic stimuli is based on a bibliographical analysis, specifically focused on the causal relationships between climatic events and their impacts. It identifies the potential sensitivity of the following strategic sectors, also called the ENAAC sectors: agriculture and forests; fisheries and aquaculture; biodiversity and landscape; economy; energy; water resources; human health; security of people and goods; transport and communications; and coastal and sea areas. The sensitivity scale used ranges from "zero" (coloured in grey) to "very high" (dark-red).[72]

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The *analysis of the adaptive capacities* of Setúbal considers three types of capacities: the current institutional adaptive capacity of the municipality; the instrumental adaptive capacity; and the sectoral adaptive capacity. With regard to the adaptive capacity of the ENAAC sectors, some territorial-based indicators were developed with the latest data available and are included and described in the text. In the analysis, the indicators refer to the average of the municipalities of the Lisbon Metropolitan Area (LMA), and the adaptive capacity index corresponds to the relationship between the adaptive capacity of Setúbal and the average capacity of the Lisbon Metropolitan Area (LMA = 100). Indicators are presented in colour scales so as to allow the comparison with the national and regional indicators and evaluate the performance.[72]

The identified climate hazards (mentioned above in "Risk Identification") were analysed and mapped. They were selected according to a criterion based on the hazards' incisiveness on the territory - the mapping of current climate hazards, which are directly demarcated as hazard areas, is provided using indirect zoning methods. The analysis of the spatial incidence of climate hazards was supported by the application of recognised scientific and technical methods adapted to a municipal scale analysis and to the available data, and was carried out separately for each type of hazard (Table 3). Maps showing different susceptibility levels for each hazard (resulting from the *susceptibility assessment* carried out for each climate hazard) within the territorial boundaries of the Municipality of Setúbal are also included in the report.

Hazards	Method of analysis
Rural/forest fires	Statistical Method: *Probability Ratio*
Soil water erosion	Universal Equation of Soil Loss (potential erosion)
Instability of slopes	Statistical Method: Informative Value
Fluvial and estuarine floods	Water-based modelinggeomorphological + PGRI + municipal ZAC + Delimitation of the centenary flood (LNEC)
Flooding and coastal overtopping	Work promoted by the Portuguese Environment Agency (PEA) that supported the Coastal Coast Program (CCP)
Coastal erosion and cliff retreat	Work promoted by the PEA that supported the CCP
Excessive heat	Spatial modelling of very hot days
Droughts	SPI index (Standardized Precipitation Index)
Wind Storms	Modeling Wasp Eng

Table 3: Methods used in the analysis and mapping of climatic hazards. Source: Assessment of current and future climate impacts and vulnerabilities in the municipality of Setúbal (2022)

To obtain the *future climatic hazards*, the susceptibility classes were projected to the end of the 21st century and adjusted to the RCP 4.5 and 8.5 scenarios. Future climatic hazards were estimated, whenever possible, quantitatively, from the territorial incidence of the current hazard and its foreseeable evolution (RCP 4.5 and RCP 8.5).[72]

The *analysis of the exposure* to current climate hazards was carried out by crossing the selected exposed elements (roads, buildings, resident population and strategic, vital and/or sensitive equipment) with the hazardous areas.[72] For the analysis of the exposure in the end of the 21st

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century, the same exposed elements were crossed with the areas identified as dangerous in 2100, in both scenarios.

The *social vulnerability assessment* of Setúbal is part of a broader study carried out at the level of the LMA. It considers a list of 43 variables representing the following domains: demography; social support; condition of the built heritage; economy; education; housing; family structure; employment; and health. The methodological procedure uses the statistical technique of dimensionality reduction called "Principal Component Analysis" (PCA) and includes eight sequential steps.[72] In the end, a total of 12 variables were retained.

The *analysis of current and future climate risks* is based on a multi-hazard risk index, which combines the susceptibility, exposure and vulnerability. The *Multi-hazard Risk Index* (MRI) is based on the INFORM international reference risk index. The risk analysis was performed for the present and for 2100, considering the scenarios RCP 4.5 and RCP 8.5. The statistical section defined in the Geographic Reference Information Base of the National Institute of Statistics was adopted as a territorial unit (UT) of analysis. The *Multi-hazard susceptibility* was calculated using the intersection of the UT with the areas likely to be affected by each of the hazards considered in the exposure assessment. Finally, the *Multi-hazard exposure* was calculated from the intersection of the UT with the buildings[t] exposed to each of the hazards considered.[u]

The risk analysis was then considered for the identification of the *priority territories at risk* (PTR).

In the report "Bioclimatic, sociocultural, economic and ecological characterization and scenarios of Setúbal" developed under the PLAAC project, future scenarios were developed for each climatic parameter considered. These are based on the results of the Metropolitan Climate Change Adaptation Plan of the LMA (2018), where future climate information (projections) was collected and treated using different models and for the climatic scenarios RCP 4.5 and 8.5. In the development of future climatic scenarios, the ensemble of regional climate models available in the Climate Portal was used for two future periods (2041-2070 and 2071-2100) starting from the ensemble of global models. The daily series of regional models of CORDEX5 were also collected for the determination of heat and cold waves as well as a series of bioclimatic indicators UTCI for the future climate. These allowed to constitute an ensemble of the regionalized models adopted in the ClimAdaPT.Local project – Model SMHI-RCA4 (regional), from MOHC-HadGEM2 (global); and KNMI-RACMO22E (regional), from ICHEC-EC-EARTH (global).[v82]

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[t] The data of resident population in the buildings comes from the 2011 Census.

[u] In the analysis, vulnerability corresponds to criticality, and was calculated for each UT independently of susceptibility and exposure.

[v] The analysis of the climatic projections includes the spatialization of the projected anomalies and the characterization of their spatio-temporal diversity. The presentation of the results is based on the morphoclimatic units (CMU), in order

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3.5.2.4 Risk Evaluation

The risk analysis carried out in the Assessment Report is based on the Multi Risk Index (MRI). The quantification of the index for the municipal area determines the Priority Risk Territories (TRP), which correspond to statistical sections having a high MRI value. The risk hierarchy identifies 5 statistical sections for current and future scenarios. The parts of the municipality with a high index are also evaluated on the basis of risk components: susceptibility, exposure and social vulnerability. A short narrative examines the specifics of the areas.[72]

3.5.2.5 Risk communication

The official documentation regarding risk assessment is publicly available on the website of the municipality. Specifically, an online database provides public access to spatial planning, risk maps and emergency plans.[83]

Ongoing projects on climate-related risks are promoted through the official communication channels[66] of the municipality. A special emphasis is placed on the strategy of communication and engagement used within the PLAAC-Arrábida project. A series of simultaneous activities were carried out and operated on multiple communication channels to ensure the involvement of multiple stakeholders, the academic community, and public entities.[84]

3.5.2.6 Administrative, financial and technical capacities

In general, Setúbal's risk assessment is included in the Municipal Civil Protection Emergency Plan. The latter, published in 2014, recognise-s the ongoing climate change process. Recently, the coordinator of the Municipal Civil Protection and Fire Service of Setúbal told the public that a revised version of the Plan is currently undergoing and taking into consideration the studies conducted in the PLAAC project.

The PLAAC project demonstrated Setubal's strong commitment to increasing knowledge and attention to climate risks. This is also demonstrated by the deep collaboration that has taken place between the technical services of the municipality, academia and the general public in this context, as well as campaigns and activities promoted by the municipality to improve knowledge of climate risk assessment and increase the involvement of local stakeholders in this area.[66]

3.6 Slovakia and Žilina city

Slovakia, a parliamentary republic, is bordered by Austria, the Czech Republic, Poland, Ukraine, and Hungary. Covering an area of 49,035 sq.km, the country is home to approximately 5.5 million people. Populations are largely spread across the country, with denser concentrations in major cities such as the capital, Bratislava. The country is divided into 8 regions (kraje), each named after its

to synthesise the regional contrasts of the projected future climate. In addition, the local particularities of these conditions, related to the different occupations of the land and urban density (URCH), are also mentioned.

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principal city, and further subdivided into 79 districts (okresy). Each region has a regional government and is further divided into (2927) municipalities, which are the smallest administrative unit, and they have their own elected mayor and council. Municipalities are responsible for a variety of local affairs, including planning and public services. At the regional level, power is exercised by the Regional Council, which is responsible for coordinating development, planning, and managing some regionally shared services. District offices execute district-level state administration, handling administrative functions and enforcing national policies within their respective districts. The highest decision-making authority in the country is the National Council of the Slovak Republic, a unicameral legislative body elected every four years. The city of Žilina is the capital of the homonymous self-governing region in the northwest, surrounded by the Western Carpathians. The region covers an area of 6,804 sq. km, contains 11 districts and has a population of 700,000, while the city itself is home to approximately 82,000 residents what makes it the fourth largest city in Slovakia.

3.6.1 Risk governance

3.6.1.1 Governance framework

The primary legislative documents concerning civil protection encompass the Civil Protection Act (42/1994), the Act on the Integrated Rescue System (129/2002), and the Act on Crisis Management (for non-war and non-wartime emergency situations) (387/2002). The *Civil Protection Act* outlines the conditions for effectively safeguarding life, health, and property from the consequences of extraordinary events. It also delineates the responsibilities of state administrative bodies, municipalities, individuals, and legal entities in ensuring civil protection for the population. The *Act on the Integrated Rescue System* defines the structure and functioning of the integrated rescue system, including entities such as fire and rescue service; the emergency medical service; the mountain rescue service; the mine rescue service; the control chemical laboratories. It serves as the legal foundation for managing diverse crises, including emergencies and disasters. The *Act on Crisis Management* delineates protocols for declaring a state of emergency, coordinating crisis management operations, and distributing resources. Furthermore, the *Constitutional Law* 227/2002 *on State Security* outlines conditions and regulations pertaining to a state of war, as well as states of emergency or exceptional circumstances, and describes emergency governance bodies at national and regional levels – security councils. Conceived as advisory entities, these bodies have the capacity to assume the roles of national and regional governmental entities during emergencies when the latter are unable to function.

The crisis management system operates across various administrative levels including central government, regions, municipalities, and designated entities for emergency response, including corporate and volunteer fire fighting corps, the Armed Forces of the Slovak Republic, the Slovak Red Cross, and other civil protection units. At district-level offices, regional civil protection and crisis management units oversee and implement activities for civilian protection. Municipalities handle

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tasks such as analysing potential crises, preparing population protection plans, conducting civil protection training, supervising local rescues, and planning and executing population evacuations. Local authorities lead emergency response within their jurisdiction. Mayors oversee municipality rescue operations, while district leaders manage responses at district and regional levels. National-level involvement occurs in large-scale emergencies (over two counties) or when state reserve resources are needed. In 2022, a commissioned study developed a proposal for the revamp of the civil protection system.

Complementary legislation addresses sector-specific risks. The Flood Protection Act (7/2010) deals with flood prevention and transposes the EU Floods Directive. The Act on Prevention of Major Industrial Accidents (128/2015) targets significant industrial incident prevention. The Critical Infrastructure Act (45/2011) involves safeguarding and managing essential infrastructure.

As a first country within Central and Eastern EU member states, in January 2023 Slovakia's government has proposed a Climate Law (LP/2023/29 Act on Climate Change and Low-Carbon Transformation). This law sets both short (long-term) climate mitigation objectives – aiming to achieve at least a 55% reduction in greenhouse gas emissions (attaining climate neutrality) by 2030 (2050), in comparison to 1990 levels. Article 10 focuses on climate adaptation. The law mandates that self-governing regions and municipalities adopt climate change adaptation strategies by April 2027. The law also establishes a Climate Council as an independent, expert advisory, coordinating, and initiative-driven body. Its task is to monitor, evaluate, and devise specific tools for climate change solutions. Comprising seven members, council terms span seven years. Annually, the council is expected to compile and present a report on the implementation of climate goals to the Parliament. The legislative bill is currently under discussion in the Parliament; however, its adoption might face obstacles due to the government's resignation in May 2023 and its replacement by a technocrat government.

3.6.1.2 Comprehensive disaster risk reduction and climate change adaptation strategies

Slovakia lacks a comprehensive Disaster Risk Reduction (DRR) Strategy in the envisioned form of the Sendai Framework for DRR 2025-2030. Rather, it has a series of high-level strategies, including *Security* and *Defence* strategies, both renewed in 2021, and National Strategy for Security Risk Management. The Security Strategy defines *essential* and *strategic* security interests. The former address independence, sovereignty, territorial integrity, the rule of law and democratic constitution, as well as protection of life and health. The latter includes, among others, national *crisis management* mechanisms; societal *resilience*; protecting the environment, public health, and cultural heritage; energy, raw material, environmental, and food security; as well as sustainable development and prosperity.

National Strategy for Security Risk Management (adopted in 2016 and revised in 2022) has similar scope as a DRR strategy. It addresses prevention, readiness, and response to security threats and

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outlines tools to enhance societal, economic, and individual resilience through integrated cross-ministerial risk management. The Strategy addresses various aspects, including institutional, expertise, technology, and coordination, to achieve resilience and effective risk management. This involves targeted stakeholder accountability, diversified financing, timely warnings, and informed public responses. The strategy specifies climate and disaster risks the country is exposed to currently - floods, landslides, windstorms, drought, diseases, epidemics, hazardous material incidents, and climate change's impacts on critical infrastructure, public health, societal functionality, supply chains, natural or cultural heritage. The Strategy spans a decade, supported by its operational arm consisting of Action Plans outlined for three-year intervals. The Action Plan 2023-2025 includes a list of actions to be executed, along with their corresponding priorities and responsible entities.

National climate adaptation strategy (NAS) was first adopted in 2014 and revised in 2018. The primary objective of the adaptation strategy is to build resilience and preparedness to cope with adverse climate change impacts. The Strategy outlines an institutional framework for effective adaptation implementation at all levels. Sub-goals of the Strategy include creating active national adaptation policies, monitoring measures' efficacy, integrating strategy aims into governance and business, raising climate awareness, fostering adaptation-mitigation synergy, using ecosystem approaches, and aligning with sustainable development, UN climate conventions, and the Paris Agreement. Government Resolution No. 478/2018 mandates the initial progress report on adaptation measures by February 2023 and tasks an update of the Strategy by December 2025[85]. A number of thematic policy strategies and plans, such as the Action Plan for addressing the consequences of drought and water scarcity, are closely connected to and complement the NAS.

The 2021 Action Plan on climate adaptation (NAP) prioritized adaptation measures, aligning with short-term (2021-2023) and medium-term (2024-2027) goals. This plan integrates climate adaptation into various sectors, proposing a vulnerability monitoring system, mid-term evaluation, and a platform for sharing positive experiences. Specific objectives refer to a range of policy areas, including water protection and management, agriculture and food security/self-sufficiency, forest management, environmental and biodiversity protection, health and well-being, and built environment. Cross-cutting measures address legislative framework, information system, risk and crisis management, research and education, and green infrastructure.

3.6.1.3 Institutional Framework

The Ministry of Interior (MoI), through its Crisis Management Section and Fire & Rescue Corps section, serves as the central authority in the field of civil protection. Central government – Ministry of Interior – coordinates the civil protection. At district levels, state appointed officer oversees planning and coordination of emergencies management, training and information gathering. Self-governing regional government contribute to developing emergency plans, cooperating with State administration for evacuations, inter-regional collaboration and population protection planning.

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Municipal authorities are tasked with planning population protection and communication within their area. They manage rescue operations, store civil protection supplies, identify shelters, and handle evacuations. They create and maintain local civil protection units, prepare the population for self-protection and mutual aid, and manage extraordinary situation declarations. Beyond civil protection, the disaster and crisis management system, as outlined in the Strategy for Security Risk Management, encompasses various central government ministries (Finance, Economy, Regional Development, Transport) and entities, including the Cadastre, Statistical Office, National Security Authority, National Forest Centre, analytical and research institutes/agencies, scientific and technical institutions, universities, and the academic community.

The Ministry of Environment of the Slovak Republic (MoE) holds the responsibility for formulating and executing the national environmental policy. This includes actions to address climate change, covering both mitigation and adaptation efforts. Two departments - Climate Change Policy Department and the Emissions Trading Department - operate under the Climate Change and Air Protection Section. The Ministry of Environment (MoE) oversees specialized agencies, including the *Water Management Enterprise* responsible for water management, the *Hydrometeorological Institute* focused on monitoring environmental and meteorological conditions, and the *Environment Agency*, which conducts comprehensive research and monitoring of the environment nationwide.

3.6.1.4 Coordination and partnership

Multi-ministerial policy coordination platforms, involving non-governmental organizations, are in place for disaster risk management and climate adaptation objectives. Activities of civil protection are hierarchically organised and summaries in emergency management plan to be developed at all levels of national and subnational governments. Slovakia has not established a DRR Platform as recommended by the SFDRR. The National and Regional Security Councils (section 3.6.1.1) are similar but narrower in scope and serve as advisory or operation bodies during emergencies. Various more or less formal coordination mechanisms are in place and the 2022 Strategy for Security Risk Management identified the need more effective institutional framework and a coordinated risk management mechanism in the context of crisis management.

The *Commission for Climate Change Policy Coordination*, established in 2012 under the Ministry of Environment, promoted a unified inter-ministerial strategy for climate policy. It included State Secretaries from various ministries, such as Economy, Agriculture, Transport, Education, Health, Finance, Foreign Affairs, and the Chairman of the Regulatory Office for Network Industries. In 2021, the Commission was succeeded by the *Council of the Government for the European Green Deal*. This Council serves as an expert, advisory, coordinating, and initiating body for the Slovak Government's involvement in the European Green Deal and the pursuit of Sustainable Development Goals. Chaired by the MoE, the Council coordinates ministries, state bodies, and partners in developing strategies, plans, and documents related to carbon-neutral economy transition. It ensures policy coherence,

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monitors implementation, and aligns with the Sustainable Development Agenda. It assesses progress, integrates insights from various institutions, and offers government recommendations. The Council comprises 34 voting members representing central government, state authorities, local governments, academia, NGOs, unions, trade associations, and others.

The 2021 National Adaptation Plan proposed the establishment of an inter-ministerial working group led by the Ministry of Environment (MoE) to oversee climate change adaptation at an expert level. This working group should ensure efficient plan implementation, monitoring and evaluation (MRE). The inter-ministerial collaboration will also include the above Green Deal Council.

3.6.1.5 Disaster Risk Financing

Financial resources and mechanisms available for covering the costs of operating and maintaining facilities related to prevention, preparedness, and response vary. The 2022 National Strategy for Security Risk Management anticipated a study analysing available financial sources and mechanisms. A key priority involves diversifying risk management financing and introducing new fiscal instruments to incorporate budgetary contributions from the Ministry of Finance.

Ministries implement prevention through national development plans and departmental strategies. Central administration can access resources from an interdepartmental budget. Personnel costs for protected interest monitoring are part of MoI budgets. The Ministry of Finance supports rescue operations and recovery expenses, averaging 1 million Euro yearly. The MoI contributes to NGOs for equipment and training to enhance their role in prevention, preparedness, response, and recovery. Funding for operating and maintenance costs related to prevention, preparedness, and response comes from the revenues generated by mandatory motor vehicle insurance (8%). These funds are redistributed for material-technical equipment and maintenance of integrated rescue system coordination centres and emergency medical service call centres. Another envisaged source of finance includes an 8% tax on non-life insurance products under the Act No. 213/2018. Local governments manage prevention within their capacity, using local fees, taxes, and other sources, to support risk management impacting vulnerable areas.

Financing of climate adaptation is based essentially on public resources (state budget, regional budgets, municipal budgets) through existing grant programs, both regional and local. The 2018 NAS highlighted the potential of European Structural and Investment Funds and other EU sources, including Horizon Europe and LIFE Program.

3.6.1.6 Systemic Resilience

Building resilience is an objective and pivotal component that runs through various national and regional strategies. However, unlike certain other nations, there isn't a comprehensive strategy dedicated to resilience. According to INFORM Risk index, Slovakia is among low-risk countries, ranked 150th, with negative outlooks as a result of climate change. In 2021, Slovakia's Human

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Development Index HDI stood at 0.848, placing it within the Very High human development category. It ranked 45th out of 191 countries.

3.6.2 Risk assessment

3.6.2.1 Framework and processes

The Civil Protection Act (42/1994) mandates the obligation to conduct a risk assessment for potential extraordinary situations, which may encompass environmental calamities, (industrial) accidents, catastrophes, public health threats, massive immigration, or terrorist attacks. Environmental calamity is defined as “extreme event with an undesired release of accumulated energy or substances due to adverse natural forces […] that negatively affect life, health, or property” (Article 3). Catastrophe (disaster) is a cumulative result of extreme events and/or accidents. The Act also establish responsibilities for assessing the risks at various administrative levels, termed "Territorial analysis regarding possible extreme events”. These assessments are carried out by state administration at the district level, compiled annually at the level of self-governing regions by the district offices in the regional capitals, and subsequently consolidated into a national assessment by the Ministry of Interior (MoI). The identified risks form a territorial registry of potential threats to life, health, and property. It's important to mention that while risks identified at the district level are unclassified, the national risk assessment is classified.

The General Director of the Crisis Section of the Ministry of Interior issues instructions on how the risk assessment should be framed and structured. The scope and process of the risk assessment have been aligned with the provisions of the Union Civil Protection Mechanism (UCPM). The 2013 methodological instruction for risk assessment built upon established processes from other sources and consisted of 9 steps, following the standard ISO approach of risk identification, analysis, and evaluation, described in the next sub-sections. Slovakia has submitted two national risk assessments, in 2015 and 2020. The 2015 National Risk Assessment (NRA) provides a comprehensive description of threats and their causal impacts, while the 2020 NRA serves as an updated version, covering all risks and identifying key risks.

The evaluation of climate change related risks is fragmented, drawing input from diverse origins and lacking a comprehensive structure for governance and procedural considerations. One of the initial studies carried out by the Hydrometeorological Institute in 2011 is the "Impacts of Climate Change and Possible Adaptation Measures in Various Sectors". This study employs a combination of desk reviews and analytical studies to evaluate key sectors for vulnerabilities. The NAS 2018 and NAP 2021 include a desk synthesis of the impacts of climate change.

Slovakia's National Communication to the UNFCCC summarizes the use of EURO-CORDEX regional climate models (RCMs) as inputs for climate risk assessment. The RCM simulations calculated ensemble averages of various climate variables across 15 to 20 model members for chosen RCP emission scenarios over time spans like 2021 to 2050 or 2071 to 2100. These simulations used the

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highest available spatial resolution (10x10 km) and were validated against meteorological observations, specifically gridded data from European meteorological stations (EOBS). The analysis was conducted for different RCP scenarios: RCP2.6, RCP4.5, RCP6.0, and RCP8.5.

3.6.2.2 Risk identification

The identification of risks begins with an inventory of exposure units, considering demographic composition of population, infrastructure, built environment (including building capacity and purpose), cultural and historical sites, and other factors. Potential risks affecting the territory are compiled using existing results, whether historical or analytical, by estimating the proportion of exposure units located in hazard-prone areas. Historical records of past extreme events are considered useful for risk identification, but Slovakia lacks a comprehensive loss data system mandated by the Sendai Framework for Disaster Risk Reduction.

The most common risks in the territory of the Slovak Republic include floods, including more frequent pluvial and flash floods in recent times, landslides, snow calamities, windstorms, fires and hazardous substances incidents, including leaks, explosions, and landfill findings. The territorial risk assessment however is expected to cover a variety of other hazards considered relevant for specific regions, including extreme temperatures, atmospheric inversions, fog, and avalanches, as well as wildfires, risks to animal and human health, pandemic risks, transportation hazards, and potential accidental releases of hazardous substances. Risk analysis

The analysis of disaster risks relies on qualitative and semi-quantitative data, including the proportion of critical infrastructure elements located in hazard-prone areas and likelihood categories of extreme events. These categories are obtained from historical sources, guest estimates, or derived from third-party sources (such as probability maps of inundation). The vulnerability analysis is conducted for each identified risk and selected category of exposure units. Specific exposure units and their characteristics are categorised and the level of the harm they can suffer from extreme event is expressed in predetermined numerical scores. The resulting vulnerability of the territory is calculated as a weighted average of the vulnerability scores.

3.6.2.3 Risk evaluation

The semi-quantitative methodology for assessing disaster risk, as outlined in the preceding subsections, involves assigning numerical values to likelihood and impacts. These values are then multiplied to produce a risk score. The likelihood rating scale ranges from 1 to 3, with 1 representing rare events that occur less than once every hundred years and 3 representing frequent events that occur approximately once every second year. Likewise, the impact rating scale from 1 to 3 indicates the significance of impacts, with 1 representing impacts at the local level, 2 indicating impacts at the regional level, and 3 signifying im-pacts at the national level. Risks with scores equal to or greater than 6, obtained by multiplying the likelihood and impacts, are considered very high or unacceptable. Risks with scores ranging from 3 to 4 are considered moderate, while risks with scores

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less than 3 are classified as low. The temporal evolution of risks is assessed in conjunction with the impact of economic, social, and environmental megatrends. Two levels, namely low and significant, are used to categorize the impacts of these megatrend on the identified risks. The regional and local assessment of risks re-lies on historical data related to damage, losses, and the magnitude of observed disruptions. Using this methodology, the 2020 National Risk Assessment (NRA) identifies a total of 62 hazards, out of which 25 are classified as key risks. Most of these key risks (20 out of 25) are amplified by climate change. Additionally, 21 of these key risks are considered to have cross-border effects. The NRA also identifies 17 low probability - high impact types of events. The hazards are classified in natural – biotic, abiotic and space-related, man-made or technological, social or sociogenic and economic. The social threats include disruption of social and healthcare provision system and disruption of the provision of emergency assistance. The economic threat includes disruption of the monetary, foreign exchange, and financial economy of the state.

3.6.2.4 Risk communication

The (unclassified) regional and (classified) national disaster risk assessments are shared among various civil protection participants as required by the Civil Protection Act. Regional assessments are either published or can be requested by interested parties as part of open government practices. The risk information from these assessments informs risk plans mandated by the Civil Protection Act and other sectoral planning instruments. Stakeholder involvement is important for aligning data, policies, measures, and finances, including investments, training, preparation, advanced analysis, and simulation of impactful but less common threats. The Act guarantees individuals the right to early warnings, evacuation, and protective information in the face of danger to life, health, and property. It also grants the right to foster preparedness through acquiring self-protection skills and aiding others. This Act mandates operators, municipalities, and district authorities to inform individuals about prevailing threats within municipal territories. The entities responsible for contributing to the development of disaster and climate risk assessments also hold the responsibility of informing stakeholders and the general public about the results.

3.6.2.5 Administrative, technical, and financial capabilities

Disaster risk assessments are performed by experts and trained personnel from state control residences at both district and national levels. Entities mandated by law are required to contribute to this process. Clearly defined responsibilities for different risk types and their national-level assessment form a crucial aspect of the overall system's capability. However, the risk assessment is predominantly qualitative or semi/quantitative in nature, often involving input from specialized agencies. The ability to conduct comprehensive, state-of-the-art quantitative assessments exceeds the current capabilities of the system. This holds true for disaster risk assessment under current climate as well as anticipation of future climate risks.

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3.7 Comparison and conclusions across the pilots

This section compares and summarizes the main points from the five pilot country desk reviews.

In the first section 3.7.1, the key findings of various risk governance systems are outlined, centring on three characteristics that are addressed according to their link to disaster risk management (DRM) and climate change adaptation (CCA) systems:

- Responsible institutions in DRM and CCA systems;
- Strategies for disaster risk reduction (DRR) and CCA;
- Official DRR platforms or coordination platforms.

The second section 3.7.2 delves into the comparative examination of the risk assessment and climate risk assessment processes adopted by the countries, regions, or municipalities. Lastly, a comparison is made among the climate-related risks identified in the five Risk Assessments (RAs) and Climate Risk Assessments/Climate Change Vulnerability Indexes (CRAs/CCIVs).

3.7.1 Main insights of the desk reviews

In most cases, the DRM and CCA systems respond to different institutions depending on the administrative level (pilot) considered. The main institutions responsible for the DRM system in the pilot regions are the Ministry of Interior (Finland; Latvia); the Directorate-General of Civil Protection of Catalonia (Catalonia); and the mayor (Setúbal; Žilina). In the field of climate change adaptation, the responsible entities are the Ministry of Agriculture and Forestry and the Ministry of Environment (Finland); the Ministry of Climate and Energy (Latvia); the Interdepartmental Commission on Climate Change (Catalonia); key entities for each ENAAC sectors – as reported in the PLAAC (Setúbal); and the Ministry of Environment of the Slovak Republic (Žilina)[w].

Although most of the pilot regions do not have a DRR and/or a CCA strategy, each of them has one or more specific instruments governing the two systems under analysis. Finland is the only pilot that implemented a DRR strategy, which is incorporated in the Security Strategy for Society (2017). Similarly, Catalonia and Setúbal are the only two pilots that established a NAS: the ESCACC30 (Catalonia) was adopted in 2023, while the Setúbal Adaptation Strategy and its Action Plan was approved in 2022. With regards to the other pilots, the main instruments governing the DRM system are the National Civil Protection Plan 2020 (Latvia); the Catalan Territorial Civil Protection Plan and the Special Plans (Catalonia); and the Municipal and Civil Protection Emergency Plan and the Municipal Forest Defense Plan (Setúbal). As for climate adaptation, among the main regulating instruments in Finland[x] and Latvia are, respectively, the National Climate Change Adaptation Plan

[w] In case the information for Žilina is not specified and/or does not exist, the national level has been considered.

[x] In 2005, Finland implemented a NAS which, nonetheless, was replaced by the NAP in 2014.

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2022 and the Climate Change Adaptation Plan for 2030 (2019). Concerning Žilina, Slovakia does not have a DRR strategy but adopted a series of high-level strategies that governs the DRM system as well as the National Strategy for Security Risk Management of 2016 (revised in 2022); in the field of climate change, the NAS was established in 2014 and revised in 2018.

With regards to the implementation of DRR platforms and/or other platforms, only one pilot (Finland) established both a DRR platform and a platform for climate change adaptation coordination. Specifically, Finland implemented a series of platforms, the main ones being the National Sendai Network (involving 26 stakeholders) and the Climate Policy Roundtable. Catalonia created the Climate Change Social Roundtable, which brings together the most relevant institutions and organisations of the region, while Setúbal is currently developing a platform for coordinating DRR activities at the level of its municipality. Although the other pilots do not have proper DRR and/or other platforms, specific bodies and/or commissions are responsible for coordination in these areas. Furthermore, in three cases, local authorities are signatories to the Covenant of Mayors for Climate and Energy (Catalonia; Setúbal), and the Covenant for Mayors (Latvia – 24 local governments).

The following table (Table 4) summarises the comparison between the main aspects of countries' risk governance systems and provides further insights/specificities for each of them.

		Finland	**Latvia**	**Catalonia**	**Setúbal**	**Žilina**
Responsible institution	DRM	Ministry of Interior	Ministry of Interior	Directorate-General of Civil Protection of Catalonia.	Mayor	Mayor
	CCA	Ministry of Agriculture and Forestry; Ministry of Environment	Ministry of Climate and Energy	Interdepartmental Commission on Climate Change	Sectoral institutions/entities	Ministry of Environment (national level)
DRR and CCA strategies	DRM	Yes	No	No	No	No
	CCA	No[y]	No	No	Yes	No

[y] See the note above.

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DRR platforms and/or other platforms	DRM	Yes	No	No	Under development	No
	CCA	Yes	No	Yes	No	No
Other insights		Official policy: 75% of the investment - and loan-based Official Development Assistance (ODA) finance to be directed towards climate action.	Civil protection and DRM are considered neglected areas by the State Audit Office due to an unclear division of responsibilities.	Catalan Climate Fund implements mitigation and climate change adaptation policies and actions. ESCACC30: 740 proposals of operational objectives and adaptation measures submitted through a public participation process. A new global indicator of adaptation was developed to monitor Catalonia's adaptive capacities to the impacts of CC	The studies carried out for the PLAAC project are being considered for the new Municipal and Civil Protection Emergency Plan. PLAAC: 200 local agents, civil societies and the private sectors contributed to lay down adaptation measures thanks to the Local Climate Adaptation Network. Since 2021, Setúbal has been part of the initiative "Making Cities Resilient 2030"	(National level) 2021 NAP: proposed the establishment of an inter-ministerial working to oversee climate change adaptation at an expert level

Table 4: Key insights of the countries' risk governance systems, based on the desk reviews.

3.7.2 Risk assessment processes: an overview

For each risk assessment and climate risk or climate impact and vulnerability assessment developed by the countries/region/municipality, the process implemented, and the institutions involved differ depending on the DRM/CCA system, the territorial scale and other specificities. This section reports the institutions and actors responsible for conducting the RAs and CRAs/CCIVs in the pilot regions.

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In Finland and Slovakia, the NRA is under direct responsibility of the Ministry of Interior. In Latvia, instead, the responsibility goes to the State Fire and Rescue Service of Latvia, which is in charge of drafting the National Civil Protection Plan - the Plan embeds the NRA. Both in Finland and Latvia, the drafting process is supported by inter-institution and stakeholders' engagement: representatives from all ministries, stakeholders and government research institutions contribute to risk assessments. As for Slovakia, it is not specified whether institutions and/or stakeholders are directly engaged in the drafting of the NRA; however, the latter brings together elements of the risk assessments carried out by authorities of the district and self-governing regions' levels. In Catalonia, risk assessments are included in the Special Plans, which are drafted by the Civil protection Commission. The same happens in Setúbal, where the Municipal Civil Protection Service elaborates the risk assessments that will be included in the Municipal Emergency Civil Protection Plan. Neither for Catalonia nor for Setúbal is it clear whether stakeholders are involved in risk assessment.

With regards to climate risk assessments, in Finland, the drafting of the "Weather and climate risks in Finland – National assessment" - carried out within the SIETO project - was supervised by the Finnish Meteorological Institute (a subordinate institute to the Ministry of Transport and Communications) in cooperation with other research institutes. In Latvia, the six sectoral risk and vulnerability assessments were carried out within the EEA project, which was coordinated by the Ministry of Environmental Protection and Regional Development; experts from the six sectors and the research institute Latvian Environment, Geology and Meteorology Centre (LEGMC) were engaged. In Catalonia, the "Impacts and vulnerabilities in natural systems, socio-economic areas and territories" was carried out in the context of the development of the ESCACC30 by the Catalan Office for Climate Change, which is attached to the General Direction of Environmental Quality and Climate Change of the Secretary's Climate Action. Finally, the "Assessment of current and future climate impacts and vulnerabilities in the municipality of Setúbal" was produced within the PLAAC project, coordinated by the Energy and Environment Agency of Arrábida in strict cooperation with Setúbal's municipality, the Faculty of Science and Technology of Universidade Nova de Lisboa (FCT-NOVA), the Institute of Geography and Spatial Planning of the University of Lisbon (IGOT-ULisboa).

Pilot region	**Type of document**	**Responsibility for RA and/or CCIV/CRA**	**Inter-institutionality/ Stakeholders' engagement**	**Other insights**
Finland	NRA ("National Risk Assessment 2023")	Ministry of Interior	Yes	The NRA and the SIETO project are two main sources of the National Climate Change Adaptation Plan

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	CRA ("Weather and climate risks in Finland – National assessment")	Finnish Meteorological institute	Yes	
Latvia	NRA ("National Civil Protection Plan")	The State Fire and Rescue Service (under the Ministry of Interior)	Yes	The State Fire and Rescue Service developed some Recommendations (guidelines) to ensure a unified approach in the risk assessment process.
	CRA (Six sectoral risk and vulnerability assessments were)	The Ministry of Environmental Protection and Regional Development	Yes	The Climate Change Adaptation Plan is also based on results from the EEA project
Catalonia	RA (Special Plans)	Civil Protection Commission	Not specified	Climate change is not considered in the Special Plans
	CCIV ("Impacts and vulnerabilities in natural systems, socio-economic areas and territories")	Office for Climate Change	Not specified.	The CCIV brings together all relevant projects carried out in Catalonia as well as the methods of analysis used in the Special Plans. In Catalonia, the key risks are those for which special plans are drafted
Setúbal	RA ("Municipal Emergency and Civil Protection Plan")	Municipal Civil Protection service.	Not specified	A current revision of the Plan is taking into consideration the risk assessment carried out for the PLAAC
	CCIV ("Assessment of current and future climate impacts and vulnerabilities in the municipality of Setúbal")	Energy and Environment Agency of Arrábida	Yes	Campaigns and activities are being organised by the municipality to promote knowledge of climate risk assessment and increase the involvement of local stakeholders
Slovakia	NRA	Ministry of Interior	Not specified	The NRA brings together elements of the risk assessments carried out by

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				authorities of the district and self-governing regions' levels
	/	/	/	/

Table 5: Main insights of risk assessment and climate risk assessment processes

3.7.3 Climate-related risks compared

The desk reviews show that the countries/region/municipalities have identified partly the same climate-related risks but with some substantial differences regarding how they are presented (Table 6) and related to the final aim for which they are identified.

Climate related risks	Finland	Latvia	Catalonia	Setúbal	Slovakia and Žilina
Geological		- Landslides	- Landslides - Avalanches	-Slope instability -Coastal erosion/cliff retreat -Soil water erosion	- Landslides
Hydrological	- Floods - Coastal/seawater floods -Changes in watercourse floods -Stormwater floods	- Floods - Floods caused by rainfall -Wind-driven floods	- Floods	- Floods - Fluvial/estuarine floods -Coastal overtopping	- Pluvial/flash floods
Meteorological	-Extreme weather - Heavy rain -Heavy snowfall - Heatwaves	- Heavy rain - Storms - Windstorms - Tornadoes -Thunderstorms - Hail - Snow and blizzards -Icing and sleets - Heat - Frost	-Irregular precipitation - Heatwaves -Marine heatwaves -Extreme weather - Heavy rain -Strong winds	- Excessive heat - Windstorms	-Snow calamities - Windstorms
Climatological	- Large scale wildfires - Forest fires	- Drought - Forest fire - Peat bog fires	- Increase in temperatures - Droughts	- Rural/forest fires - Drought	

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	- Drought - Sea level rise	- Reduction of frost	- Dry spells - Rising sea temperature - Decreased cold hours in winter - Sea level rise - Forest fire - Acidification		
Biological/ environmental	- Changes and loss of habitat and species -Increase in endangered species -Deterioration of ecosystem services -Increase in alien species	- Epidemics/ Pandemics - Epizootics - Epiphytotic -Changes in seasons -Pest and pathogen outbreaks - Displacement of native species - introduction of new species - Heat strokes - Desiccation - Eutrophication	- Evapotranspiration		
Socio-economic	- Transitional risks - Energy supply disruption - Water supply disruption - Disruption in food production - Effects on critical infrastructures - Long term increase in the investment and maintenance	- Interruption of critical services - Power-supply disturbances - Increase in runoff/hydropower fluctuations - Reduction of water runoff in summer - Damage to infrastructure/overheating of equipment	- Reduced water availability		

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	cost of the electricity network				
Security	- Migration - Civil disturbances				

Table 6: Climate-related risks as reported in the official sources (RA, NRA, CRA,CCIV) considered in the desk reviews.

The table below (Table 7) summarises the climate and socio-economic scenarios, where available, used in the NRA, RA, CRA, CCIV of the pilot regions.

Country/region /municipality	**Risk Assessment/ Climate Risk Assessment/ Climate Change Impact and Vulnerability Assessment**	**Climate scenarios used**	**Socio-economic scenarios used**
Finland	RA (National Risk Assessment)	V: mean annual temperature and precipitation M: 28 global climate change models Y: period 2000-2085 (ref. period 1971-2000) S: four RCPs.	/
	CRA (SIETO project)	M: 28 global (CMIP5) and regional (EURO-CORDEX) models Y: periods 2000-2085 (ref. period 1971-2000). S: four RCPs.	- Optimistic scenario (with effective management of challenges) - Pessimistic scenario (with high inequality and a weak economy).
Latvia	RA (National Civil Protection Plan)	Climate extremes are considered from the aspects of their frequency, intensity, and duration (compare to the previous time period); and whether they occur earlier or later according to the seasonal pattern.	/
	CCIV (EEA project)	V: air temperature, rainfall, wind speed, snow cover M: multiple climate models (adapted to the country by bias correction and statistical downscaling methods) S: RCP4.5 and RCP8.5 SD: yes	/

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Catalonia	RA (Special Plans)	/	/
	CCIV (ESCACC30)	M: three globalized models, MPI-ESM; GFDL-ESM2G; CanESM2 Y: periods 2021-2030 and 2021-2050 (ref. period 1971-2000) S: RCP4.5 and RCP8.5.[z]	/
Setúbal	RA (Municipal Emergency and Civil Protection Plan)	/	/
	CCIV (PLAAC project)	M: different models (CORDEX daily series for heat-cold waves; UTCI bioclimatic indicators for the future climate) Y: periods 2041-2070 and 2071-2100 S: RCP4.5 and RCP8.5	/
Slovakia and Žilina	NRA (National Risk Assessment 2020)	/	/
	CRA (The eight National Communication of the Slovak Republic on Climate Change)	M: EURO-CORDEX (with 15-20 model) S: four RCPs Y: time intervals (up to 2100)[aa] -simulations validated against meteorological observations (EOBS).	/

Table 7: Climate and socio-economic scenarios used in the pilots. ***Y****= Time period;* ***M****= Climate model;* ***S****= Scenario;* ***SD****= Spatial data;* ***V****= Variables*

3.8 Review of academic research in the pilots

This analysis aims to understand how the scientific community of Finland, Latvia, Catalonia, Setúbal, and Žilina assess the climate-related risks affecting their respective territories. In particular, it

[z] In Catalonia, the climatic variables are projected with a high-resolution of 1km.

[aa] The climatic variables are projected with a high-resolution of 10x10km.

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examined scientific studies focusing on climate risk, vulnerability, and resilience assessments in recent years (2015-2023).

The tools used to conduct this analysis are Scopus and ResearchRabbit. On Scopus, specific filters were used to select relevant publications in this field, including the time period (2015-2023) and the following keywords: TITLE-ABS-KEY (**name of the country or region or municipality** AND ("risk assessment" OR "vulnerability assessment" OR "resilience assessment") AND "climate change"). The resulting documents that did not specifically address the topics of interest were excluded. Finally, the selected documents were imported and uploaded onto ResearchRabbit, where the search continued by searching for similar papers using the option "similar works".

The research centred on Finland resulted in 9 papers (7 Scopus; 2 ResearchRabbit). Two studies analyse the *risk of floodings*: the first study by Leijala et al. (2017)[86] used a location-specific statistical method to evaluate the flood risk on the Finnish coast based on the joint effect of long-term mean sea level change, short-term sea level variability, and wind-generated waves. The second study by Jato-Espino et al. (2018)[87] developed a methodology based on a Multiple Regression Analysis (MRA) to analyse the flood risk in urban catchments; stormwater models were replaced by a combination of Multiple Linear Regression (MLR), Multiple NonLinear Regression (MNLR) and Multiple Binary Logistic Regression (MBLR). In the field of *agriculture*, a study by Tao et al. (2015)[88] analysed the climate change impacts on wheat production and water use through a super-ensemble-based probabilistic projection system that uses 6 climate scenarios and 20 crop model parameters. Another study by Pirttioja et al. (2019)[89] analysed the likelihood of the impacts on crop yield under probabilistic climate change using Impact Response Surfaces (IRSs) constructed from a set of sensitivity simulations that explore yield responses to a wide range of changes in temperature and precipitation. Finally, Purola et al. (2018)[90] assessed climate change impacts at the farm level in the province of North Savo by using the biophysical MCWLA model and the DEMCROP model simulations (based on a 2050s scenario). As for the *forestry sector*, a study by Lehtonen et al. (2018)[91] studied the impacts of projected climate warming by 2100 on soil frost conditions and, consequently, on bearing capacity of different forest and soil types in Finland, in relation to wintertime wood harvesting conditions and transport availability on forest truck roads. Global climate model (GCM) data were extracted from the CMIP5 database, while regional climate model (RCM) simulations were constructed within the EURO-CORDEX project; RCP4.5 and RCP8.5 were considered until 2099. A study by Venäläinen et al. (2017)[92] analysed the *risk of wind storms* in the Finnish forests with a wind multiplier method so as to identify the locations subject to the highest forest wind damage risks; the 20m-spatial resolution CORINE land-use dataset and high-resolution digital elevation data were used. Regarding the *health sector*, a study published in 2021 by Landreau et al.[93] analysed the heat risk combining socio-economic and climatic projections; it used climatic heat hazard data for three different RCPs (RCP2.6, RCP4.5, and RCP8.5) and vulnerability and exposure data for five global SSPs up to 2100. Finally, a study by Pilli-Sihvola et al. (2018)[94] assessed

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the *resilience* of Finland to climate-related risks. Specifically, it evaluated the institutional coping capacity of the country through the analysis of Finland's DRR and CCA approaches as well as whether the current methods of determining vulnerability and exposure neglect some risks related to climate change. It is based on qualitative data collected in two research projects which analysed weather and climate-related risks in the country.

With regards to the research carried out for Latvia, 4 papers were found, only on Scopus. The first study by Zeverte-Rivza et al. (2017)[95] identified and assessed risks in *agriculture* in the context of climate change. It summarised the political framework of assessing and mitigating climate change and the risks related to it and described the impacts of agriculture on the national economy. The second study by Siksnane and Lagzdins (2022)[96] does not directly address climate change but investigates the effects of meteorological and hydrological conditions of the past 25 years on water quality to understand whether the increase in seasonal and annual patterns of precipitation, air temperature, and runoff increase *the risks of nutrient losses* from agricultural catchments in the future. Sarauskiene et al. (2015)[97] analysed the *flood pattern changes* in the rivers of the Baltic countries applying trend and frequency analysis for different periods (from 1922 to 2010). A comparative study of five probability distributions was performed in order to estimate which distribution at best represents statistical characteristics of the flood data. Finally, Feofilovs and Romagnoli (2020)[98] assessed the urban *resilience* to natural disasters of a Latvian municipality (mainly affected by floods) using a system dynamic tool that integrates two methods, a multi-criteria analysis and a system dynamic model, which were used to create a dynamic Urban Resilience Index. The research focused on linking climate adaptation and DRR strategies.

As for the autonomous community of Catalonia, 9 papers were found on Scopus and 2 on ResearchRabbit. Four studies are specifically focused on the Catalan *coasts*. The first study by López-Dóriga and Jiménez (2020)[99] assessed the impacts of sea-level rising on the low-lying coastal areas of Catalonia. A methodology for improved SLR-induced flood-damage assessments in natural areas is presented in the paper - it is composed of a pseudo-dynamic method coupling equilibrium-based coastal response and classical bathtub modelling approaches and a simple method to account for habitat conversion following inundation. Sanuy and Jiménez (2019)[100] assessed the coastal response of the Tordera Delta, namely a curvilinear sensitive deltaic coast with coarse sediment and steep slopes, to storm-induced hazards using a model setup composed of the SWAN and XBeach models. In the third study, Sayol and Marcos (2018)[101] presented a new methodology to estimate the impact of local sea-level rise and extreme surges and waves in the coastal areas of the Ebro Delta are estimated under RCP4.5 and RCP8.5 scenarios. Finally, Roca et al. (2018)[102] adopted a systemic and quantitative perspective to assess planning systems and stakeholder relationships in connection with the coastal risk by applying a network analysis to the Catalan coast, paying attention to the level of climate change integration in the planning system. A study by Royé et al. (2020)[103] assessed the effects of *heat wave* intensity on the mortality in four cities of Spain (including Barcelona)

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through the Excess Heat Factor (EHF). The latter is based on the comparison of a three-day average daily mean temperature with the annual temperature threshold in that specific location, and the measure of the temperatures reached during that three-day period compared with the previous 30 days. In the field of the *forestry* sector, Lecina-Diaz et al. (2021)[104] assessed the risk of losing forest ecosystem services due to wildfires in Catalonia by taking into account exposed values, hazard magnitude, susceptibility and lack of adaptive capacity of the Catalan forests; different data sources were used to define the indicators of the risk components. A study by Gil-Tena et al. (2019)[105] evaluated whether the degree of risk to the persistence of monospecific forests posed by climate change, fire, and land-use changes varies depending on seral stages, tree species, and climate gradients in the short and medium terms. The risk assessment, focused on the forests of Catalonia, was performed through a combination of correlative and process-based modelling approaches and future global change scenarios. Another study, by De Cáceres et al. (2015)[106] aimed to predict the drought stress on some tree species of the Catalan forests. In the analysis, a designated and validated water balance model producing annual estimates of drought intensity and duration was coupled with forest inventory data. Andersson et al. (2021)[107] assessed *resilience* around green and blue infrastructures (GBI) in three case studies, including Barcelona. Building on practice developed around participatory resilience assessments, they created a three-filters framework - the three filters being infrastructures, institutions, and the perceptions of individual beneficiaries - that follows a three-step knowledge process for assessing and building resilience around the flow of benefits from GBI. The resilience in urban ecosystem services is also assessed by De Luca et al. (2021)[108]: they investigated the presence of resilience thinking in the city's GBI-relevant policies through the application of the urban ecosystem services resilience assessment matrix, co-develop scenario narratives of possible futures and their implications for ES, and apply the narratives through a participatory approach to enhance stakeholder thinking on adaptive policies based on possible shifts in ES provision and needs. Finally, a study by Petit-Boix et al. (2017)[109] determined the feasibility of post-disaster emergency actions implemented after a flood event in the Maresme region (Catalonia) through an integrated hydrologic, environmental and economic approach, using life cycle assessment (LCA) and life cycle costing (LCC) to determine the eco-efficiency of these actions. Their net impact and payback were calculated by integrating avoided flood damage.

The research on the municipality of Setúbal resulted in 2 papers found only on Scopus. In particular, the two studies focus on the risk and vulnerability assessment of the *historical cultural heritage* of the municipality. The first study by Resta et al. (2018)[110] was carried out within the project STORM (Safeguarding Cultural Heritage through Technical and Organisational Resources Management). It assessed the climate-related risks and natural hazards of the Roman Ruins of Tróia, Setúbal - one of the five pilot areas selected in the project - through a risk assessment method supported by the evaluation of historical records, real-time on-site monitoring, regional climate projections, and statistically downscaled time series. Climate indices were also evaluated for obtaining a more

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complete picture of the situation. The second study by Ravan et al. (2023)[111] contributed to the development of an indicator-based vulnerability assessment framework for cultural heritage sites, specifically applied to the archaeological site of Tróia, Setúbal. The results indicate the areas of sensitivity and the coping and adaptive capacities of the site, which form the level of risk and vulnerability.

With regards to Žilina, no documents were found on Scopus. For this reason, the focus was shifted on Slovakia and resulted in 9 documents found on Scopus. Flood risk analysis is explored in depth in 5 papers. The study by Mitkova et al. (2019)[112] used the bivariate statistical analysis of the joint impact of synchronous discharges for estimating the flood risk on Hron River and its tributary Slatina in Central Slovakia. The methodology improved by the researchers aim to evaluate flood risk in situations where floods occur on two or more rivers that are joined together at the same time. Another study by Vojtek et al. (2021)[113] identified areas susceptible to flooding by using two different approaches, namely a multi-criteria decision analysis-analytic hierarchy process (MCDA-AHP) and a machine learning-boosted classification (BCT) and boosted regression tree (BRT). Specifically, for the study area of the Topľa River Basin, seven flood conditioning factors were used to identify the flood susceptibility of the area. Zeleňáková et al. (2019)[114] developed a new approach for risk assessment of water management actions within FPO projects (flood protection objects). The analysis and assessment of environmental impacts of FPO in Snakov village was done using the universal risk analysis matrix UMRA and a qualitative and semi-quantitative assessment matrix. The study by Solín (2020)[115] focuses on flood risk governance analysis in Slovakia with the application of the analytical framework of the EU-FP7 STAR-FLOOD project. Bubek et al. (2019)[116] presented a Europe-wide assessment of current and future risk of railroad track flooding for different global warming scenarios, using an infrastructure-specific damage model. Based on an ensemble of climate projections for RCP8.5, they showed the increase in current risk for rail networks in different countries, with a high estimate of the risk for Slovakia in a 3°C scenario. The study by Lückerath et al. (2020)[117] presented the application of a vulnerability analysis for the city of Bratislava. Through the help of a standardized process for assessing climate change-related risks and vulnerabilities in cities and urban environments (IVAVIA-Impact and Vulnerability Analysis of Vital Infrastructures and Built-up Areas) developed under RESIN, the research analyzes the effects of extreme precipitation on the city's road network. The study by Härt et al. (2015)[118] analyzed the effects of providing a given ecosystem service on cost-effective harvesting schedules and how harvesting schedules will be affected by climate change. For two study regions, in Slovakia and Austria, some ecosystem services are evaluated within climate change scenarios. The research by Rome et al. (2019)[119] is developed within the EU project Climate Resilient Cities and Infrastructures and aimed at devising a risk-based vulnerability assessment process of urban systems, including built-up areas and critical infrastructures.

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This analysis aimed at collecting recent studies (2015-2023) focused on the assessment of risks, vulnerability and resilience related to climate change in Finland, Latvia, Setúbal, Catalonia and Slovakia. For each territory, the selected papers were presented, and the methods and models used in the different analyses briefly summarised.

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4 Requirements for CLIMAAX risk assessment toolbox

This section outlines the CLIMAAX risk assessment toolbox requirements, informed by consultations with the five pilot sites and an analysis of existing publicly available toolboxes. We determine gaps in current risk assessment toolboxes that hamper their application at the regional to local scale, based on which recommendations for the CLIMAAX toolbox are developed.

4.1 Assessment of pilot needs for a climate risk assessment toolbox

We established the pilot site needs for the CLIMAAX toolbox in a two-step process, in close collaboration with WP3. First, we distributed a questionnaire with over forty questions to make an inventory along four main themes: Main climate hazards; Risk assessment methods; Data needs; Desired outcomes (see Annex 3 for the whole questionnaire). The questionnaires were completed and returned by the project kick-off meeting which took place in January 2023. Second, we conducted two-hour scoping meetings with each pilot site to gain a more detailed understanding of the data and methods already in use. The questions posed during these meetings revolved around the same four themes that were covered in the questionnaire.

Due to different regional contexts (e.g. climate zone, legislation, available resources), the needs in the pilot sites for using a toolbox (and the related required capabilities) deviate considerably (see Annex 4 for a detailed overview). This especially pertains to the **main climate hazards** in the different regions. While flooding (coastal, riverine, flash) is a common hazard in all pilots, drought, wildfires, and windstorms are prevalent in four pilot sites. Furthermore, three pilot sites identified heat extremes as a hazard in their region and two sites experience coastal erosion. Additional hazards in individual pilot sites are e.g. heavy snowfall (Catalonia) and blizzards (Finland), flooding due to snowmelt (Latvia) and landslides (Setubal).

According to the pilot site partners, current **risk assessment methods** range from simple hazard-based risk indices (e.g. Latvia, Finland) to comprehensive analyses of expected losses, incorporating hazard, exposure, and vulnerability information (Catalonia).

Accordingly, **data needs** differ substantially across pilot sites, and in summary the pilot needs for risk data revolve around the following domains:

- Hazard data of past events and future projections, based on return periods (for planning) and single events (for e.g. stress-testing),
- Socio-economic data to characterize exposure and vulnerability, both observed and future scenarios (e.g., population, urbanization, land use projections)
- High-resolution data in raster format (e.g., 1x1km2) and/or vector format (e.g. NUTS regions) matching the spatial scale of the information needs in the regions of interest,
- Preference for locally collected and managed data, but also interest in global and European-level data.

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When it comes to the **desired outcomes** of the CLIMAAX toolbox, all pilot sites are interested in a tool that can help communicate current and future climate risks with policy makers, thereby supporting adaptation planning. Further, three pilot sites (i.e. Latvia, Zilina, Setubal) would like to receive technical guidelines for comprehensive risk assessments, while Catalonia, Zilina, and Finland are particularly interested in a toolbox offering scenario-based risk assessment approaches. Additional desired outcomes are an evaluation tool for early warnings, information for stress-testing as well as validation of previous climate risk assessments.

4.2 Requirements for a risk assessment toolbox and examples of existing risk data platforms

Due to the diverse set of needs established across the pilot sites, the following **four main requirements** for the CLIMAAX toolbox were determined:

- Flexible tool to include own data and custom risk assessment procedures based on open code and technical guidelines.
- Offer a range of risk assessment approaches at high spatial resolution, i.e., consistent with the spatial scale at which information in the region is needed.
- Possibility to assess risks imposed by a variety of climate hazards under present and future conditions.
- Possibility to analyse different exposed elements (e.g. population, infrastructure, buildings) and their vulnerability under present and future conditions.

To meet these requirements, examples of already **existing pan-European risk assessment tools** were consulted in a first step, pursuing a two-fold aim: a) to understand the limitations of these existing tools in meeting the pilot needs, and b) to get inspiration for the design of the CLIMAAX toolbox.

Risk Data Hub

The European Commission Disaster Risk Management Knowledge Centre’s (DRMKC) Risk Data Hub provides an easy-to-use mapping tool that visualizes pre-calculated risks for a range of hazards, exposed assets, and a generic (i.e. hazard-independent) vulnerability indicator at NUTS0 up to NUTS3 level. While the Risk Data Hub provides a useful first risk estimate, its functionality beyond the pre-calculated risks, for instance by integrating own data or risk assessments procedures, is limited. Furthermore, risk assessments based on geospatial raster data as well as the integration of vulnerability into the assessment are currently not possible.

CLIMADA

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The open-source impact model CLIMADA can be used for probabilistic climate risk assessments based on damage calculations.[120] The global-scale model has been established for several hazards including tropical cyclones, European winter storms, and wildfires, the data of which are publicly available through an Application Programming Interface (API). Additionally, the model allows for integration of custom code and data and provides detailed documentation and guidelines. However, CLIMADA only allows for conducting damage-based risk assessment approaches and is not designed to assess risks posed to exposure populations. Further, customizing the model requires technical expertise and training.

Climate-ADAPT

Climate-ADAPT is a European Climate Adaptation Platform maintained by the European Environmental Agency (EEA), aiming to support decision-making concerning climate change adaptation through data and information sharing on a variety of topics related to climate change impacts and adaptation options. It provides a platform with guidelines, handbooks and step-by-step instructions useful for national-level policy makers and coordinators that develop adaptation plans, including map viewers for different hazards and social vulnerability relevant for urban adaptation. While the platform is very informative, it includes little technical guidance for conducting risk assessments, nor is it designed for interactive use such as analysing one's own data.

Copernicus Climate Data Store (CDS)

Last, the Copernicus Climate Change Service Climate Data Store (CDS) maintained by the European Centre for Medium-Range Weather Forecasts (ECMWF) provides a wide range of climate-related hazard data, based on observed records as well as future climate projections. The CDS provides elaborate documentation on how to use the toolbox, as well as open-access code and data access through an API. However, CDS primarily focusses on the provision of hazard data rather than risk assessments procedures and does not provide guidance on how to select or process these data for a risk assessment.

Comparison of the established pilot needs with the functionalities of the existing pan-European toolboxes described in the preceding sections has revealed that most of the requirements for the CLIMAAX toolbox are met in one or another toolbox, but that none of the available toolboxes fulfils all requirements. Therefore, the CLIMAAX toolbox will draw upon the existing toolboxes by adopting risk assessment procedures, data, and guidelines, and will collate these pieces of information in one open-access, consistent, and customizable toolbox across Europe. Furthermore, the CLIMAAX toolbox will extend this synthesis of available tools with additional risk assessment workflows based on an extended selection of hazards and various risk assessment procedures. This should also include future dynamics in exposure and vulnerability under a range of socioeconomic scenarios such as the Shared Socioeconomic Pathways (SSPs) until the end of the 21st century at a high spatial resolution that is useful for regional-level climate risk assessments. A first set of such risk

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assessment workflows is provided in the following section. Deliverable 3.1 will provide a first mock-up of the CLIMAAX toolbox.

4.3 Preliminary Risk Workflows

The CLIMAAX toolbox will be structured to accommodate all the requirements described in section 4.2. In particular, the toolbox will allow each user to select different features schematized in Figure 4 by different numbers:

- 1-2) Visualize/download both desired hazard (1) and exposure, and/or vulnerability (2) data. Users will also be able to upload their own local data.
- 3) Download pre-defined risk maps and assessment results (3),
- 4-5) Create customized regional risk assessment (4) based on specific risk workflows (5)
- 6) Consult the CLIMAAX guidelines with respect to regional climate risk assessment, description of the risk workflow of points 4 and 5, and technical description of how to perform more advance methods such as downscaling and probabilistic risk assessment.

It is envisaged that customized risk workflows and hazard, exposure, and vulnerability data will be available both for historical and future scenarios. Those data could be then exported either as a raster image of 1X1km or at NUTS resolution.

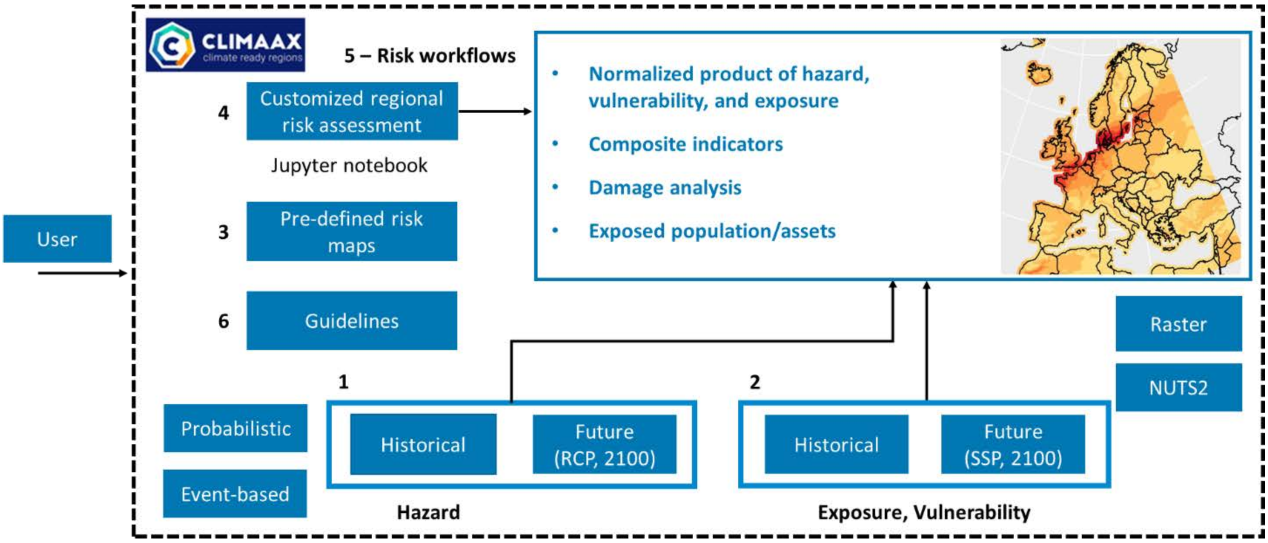

Figure 4: Schematic representation of the CLIMAAX toolbox structure. H, V, and E represents hazard, vulnerability, and exposure respectively

In the initial conception of the CLIMAAX toolbox, different sample risk assessment workflows were identified and implemented. Each workflow follows a 'stepwise' data processing scheme to calculate risk as a combination of hazard, exposure and vulnerability information. The code to compute the workflows was selected from existing research following a review process based on the following criteria:

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- Scientific research with sufficient number of citations;
- Official EU reports;
- Frameworks implemented in the CLIMAAX pilots.

Other important criteria for the risk workflow selection are that (a) they should be feasible to be implemented within the CLIMAAX toolbox, and (b) they should be understandable and comprehensive also for users that are not trained in the technical or conceptual construction of risk assessment tools.

Table 8 summarizes the risk workflows that have been identified in the current pilot version of the toolbox. For each workflow, the table describes the types of hazards, risk assessment methods, and hazard, exposure, and vulnerability data included in the toolbox.

Risk workflow title	**Risk (R) assessment**	**Hazard (H)**	**Exposure (E)**	**Vulnerability (V)**
Floods	Damage analysis	Water depth	Land-use	Damage curve
Drought	Product between hazard, exposure, and vulnerability	Statistical indicators (e.g. Standardized Precipitation Index)	Cropland, livestock density, water stress, population	Vulnerability index
Exposed drought population	Overlay between drought hazard and exposure	Combined drought index	Population	-
Wildfire	Product between hazard, exposure, and vulnerability	Hazard matrix between susceptibility and fuel type	-	-
Storm	Damage analysis	historical storm footprints	Land-use	Damage curve
Blizzard	Product between hazard and exposure	Probability of blizzard	Infrastructure data	-

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Snowfall	Product between hazard and exposure	Mean annual number of snowfall days	Infrastructure data	-

Table 8: Summary of the risk workflow characteristics implemented in the CLIMAAX toolbox.

While the hazard data needed for each workflow depend on the type of hazard (e.g. water levels are used to characterized flood hazard and not heatwave), exposure and vulnerability data do not change with respect to the type of hazard (e.g. population data can indicate both vulnerabilities to floods and droughts). An overview of potential geospatial datasets that we envision to use to characterize exposure and vulnerability across workflows is provided in Table 9. This first overview of datasets will be extended and scrutinized in the coming months, with a final selection of data presented in Deliverable 2.3 (due in Month 18). Additional datasets to be implemented in the toolbox are also reported in the following description of the risk workflows.

		Variable	**Dataset**	**Temporal resolution**	**Spatial resolution**	**References**
Exposure	Social	Population	Global Human Settlement (GHS)-POP	1975-2030	100m, 3 arc seconds	[121]
			WorldPop	2000-2020	3 arc seconds	[122,123]
			Population projections	2020-2100	30 arc seconds	[124, 125]
	Physical	Infrastructure	Open Street Map (OSM)	most recent	polygons	[126]
			Critical Infrastructure Spatial Index (CISI)	2021	0.1 degree	[127]
		Buildings	OSM	most recent	polygons	[126]
			Microsoft	most recent	polygons	[128]
		Land cover	Coordination of Information on the Environment (CORINE)	1990, 2000, 2006, 2012, 2018	100 m	[129]
			Land-Use based Integrated Sustainability	2012, 2018	50 m	[130]

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			Assessment (LUISA)			
			Urban land projections	2020-2100	1 km	[131, 132,133]
Vulnerability	Social	Age	Gridded Population of the World (GPW) v4.11	2010	30 arc seconds	[134]
		Education	Subnational Human Development Index (SHDI)	~2010	Administrative units	[135]
		Income	SHDI	~2010	Administrative units	[135]
		Healthcare access		2019	30 arc seconds	[136]
		Settlements	GHS-Settlement Model (SMOD)	1975-2030	1 km	[121]

Table 9: Potential exposure and vulnerability geospatial datasets to use in the pan-European CLIMAAX toolbox.

In the following subsections, each workflow is described by first introducing the main *risk approach* and components to define risk, such as *hazard*, *exposure*, and *vulnerability* Then, we show the preliminary output of the toolbox based on the specific risk workflow. Finally, we describe the *planned extensions* such as the use of future hazard, exposure, and vulnerability data.

4.3.1 Flood

Risk approach: In this workflow on flood risk, all the inputs are provided as raster data. The steps used in this method are summarized in the figure 5 below. The workflow combines hazard, exposure and vulnerability to assess the expected flood damage per year[137]. Hazard information is based on probabilistic water depth information for a given return period, i.e., the likelihood of an event to occur[138]. This information is provided based on either historical or future climate change scenarios, without account for the presence of existing flood defence systems. The hazard information is then linked with the exposure (land use) and vulnerability (damage curve) to assess flood risk. In particular, for each grid cell flood depth is combined with exposure data on land use- or building types by using stage-damage curves. These stage-damage curves (also referred to as 'vulnerability curves') show for each flood water level how much damage can occur (as a percentage of the maximum damage).

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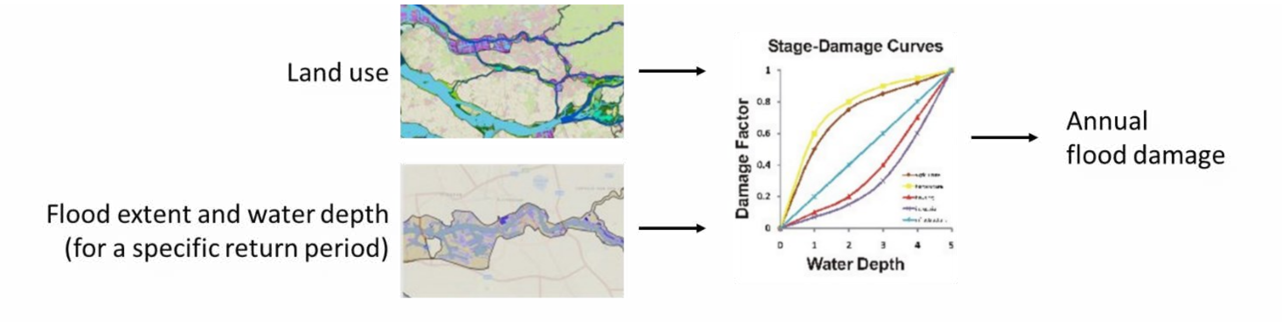

Figure 5: Schematic representation of the flood risk workflow

<u>Hazard</u>: Flood water depths and extent maps are used as hazard information in this workflow. These data are available from the European Commission's Joint Research Centre (JRC) repository for return periods of 10, 20, 50, 100, 200, and 500 years, based on historical information. The flood extent-depth map has a spatial resolution of $100m^2$.

<u>Exposure</u>: The land-use information for a specific year is used as a proxy for exposure. In this workflow we use CORINE land cover information ($100m^2$ spatial resolution) available at European level for 1990, 2000, 2006, 2012, and 2018.

<u>Vulnerability</u>: This indicator is represented by a damage curve (or stage-damage curve) which shows, for a particular land-use category, how much of a fraction ('damage factor') of the maximum value at risk is reached at a particular inundation depth. In this risk workflow we used damage curves, based on historical damage data, available at the JRC repository.

<u>Output:</u> An example of flood damage assessment based on application of this workflow on the Zilina CLIMAAX pilot is reported in Figure 6. The spatial resolution of the risk map is of $100m^2$, as previously mentioned.

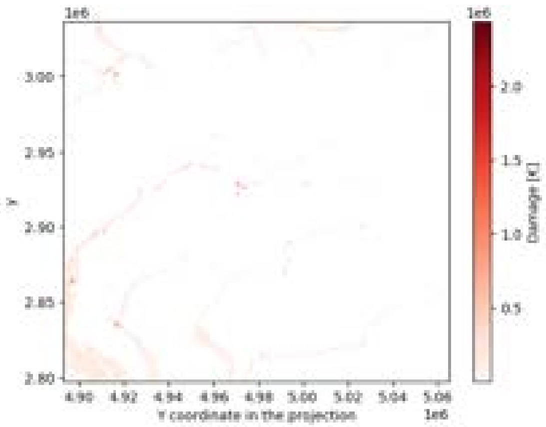

Figure 6. Flood damage in the Zilina pilot case considering a hazard of 500 years return period.

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Planned extensions: Next versions of the toolbox will also include the information about future hazard conditions for assessing flood risk.

4.3.2 Drought

Drought risk is the potential for adverse impacts or consequences of droughts, it is often quantified by the product of hazards, exposure, and vulnerability. To date there is a range of approaches for assessing drought risk, and its components.[139]

Risk approach: IIn this drought risk workflow, we follow the hazard-exposure-vulnerability framework,[140,141]. For the purposes of this toolbox, we plan to follow the work of Carrão et al. (2016)[140], reproducing a drought risk map for the European Union at NUTS2 spatial resolution for historical (1960 -2019). This risk map represents the product between hazards, exposure, and vulnerability. This is done by normalizing those regional values against the maximum value in the map to obtain a scale between zero to one.

Hazard: Drought hazard for a given region is estimated as the probability of exceedance of the median of European severe precipitation deficits for a specific reference period, either historical or future. In the reference period (1960 -2019). Carrão et al. (2016)[140] use the weighted anomaly of the standardized precipitation (WASP) index to define the severity of precipitation deficit. The WASP-index takes into account the annual seasonality of the precipitation cycle and is computed by summing weighted standardized monthly precipitation anomalies. For this workflow, historical daily global gridded climate related forcings from the GSWP3-W5E5 dataset (ISIMIP3a; ISIMIP Repository) at a 0.5-degree spatial resolution, covering the years 1901-2019, will be used.

Exposure: Drought exposure is assessed by means of the data envelopment analysis (DEA) approach that quantifies the relative exposure of a region from a multidimensional set of indicators. The different indicators of drought exposure are:

- Gridded global cropland at 5 arc minutes resolution for 2010.[142]
- Gridded global livestock density at 5 arc minutes resolution for 2010.[143]
- Global sub-basin scale/gridded baseline water stress (BWS) calculated as the ratio of local water withdrawal over available water supply for the baseline year of 2010. BWS can be taken as an historical average from Aqueduct 3[144] or calculated based on the Global ISIMIP3 CWatM simulations[145].
- Gridded global population at 2.5 arc minutes resolution for 2015.[146]

The DEA approach accounts for the spatial distribution of crop areas and livestock, water stress BWS, and human population. This approach defines highly exposed regions in case at least one type of indicator is predominant. For example, an agricultural region that is completely covered by rainfed crops is fully exposed to drought, independently of the presence of other elements at risk.

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- Vulnerability: Vulnerability to drought combines aggregated proxy indicators representing the economic, social, and infrastructural factors of social vulnerability (see Table 10) at each geographic location. Fist, indicators for each factor are combined using a DEA model, as similar as for drought exposure. In the second step, individual factors resulting from independent DEA analyses are arithmetically aggregated (using the simple mean) into a composite model of drought vulnerability.

Factors	Indicator	Scale	Correlation	Source
Economic	Energy consumption per capita	National	Negative	International Energy Agency
	Agriculture (% of GDP)	National	Positive	World Bank
	GDP per capita	5 arc minutes	Negative	Kummu et al., 2019. 147
Social	Rural population (% of total population)	2.5 arc minutes	Positive	146
	Literacy rate (% of people ages 15 or above)	National	Negative	World Bank
	Improved water source (% of rural population with access to water)	National	Negative	World Bank
	Life expectancy at birth (years)	National	Negative	World Bank
	Population ages 15 -64 (% of total population)	National	Negative	World Bank
	Government effectiveness	National	Negative	World Bank
Infrastructure	Agricultural irrigated land (% of total agricultural land)	5 arc minutes	Negative	IFPRI, 2019
	Road density (km of road per 100 km2 of land area)	Vector	Negative	Global Roads Open Access Data Set (gROADS version 1 GRoadSv1 148

Table 10: Input data used in this risk workflow to calculate the drought vulnerability.

Output: The main output from this workflow is a drought risk map with the same spatial resolution of the hazard, exposure, and vulnerability data.

Planned extensions: Risk assessment for future scenarios (2020 -2100) will be added in the next versions of the toolbox.

4.3.3 Exposed drought population

Another approach for assessing drought risk is the calculation the exposed vulnerable population to drought. This can be done by overlaying the hazard data of drought, expressed through Combined Drought Indicator (CDI), and population data.

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Hazard: The Combined Drought Indicator (CDI) that is implemented in the European Drought Observatory (EDO) is used to identify areas affected by agricultural drought, and areas with the potential to be affected. In the current version of the toolbox we use the CDI provided by Copernicus. CDI can be downloaded from the Copernicus server and is derived by combining three drought indicators produced operationally in the EDO framework - namely the Standardized Precipitation Index (SPI), the Soil Moisture Anomaly (SMA), and the FAPAR Anomaly - in such a way that areas are classified according to three primary drought classes: (1) “Watch”, indicating that precipitation is less than normal; (2) “Warning”, indicating that soil moisture is in deficit; and (3) “Alert”, indicating that vegetation shows signs of stress. Two additional classes - namely “Partial recovery” and “Recovery” - identify the stages of the vegetation recovery process.

Standardized Precipitation Index (SPI): The SPI indicator measures precipitation anomalies at a given location, based on a comparison of observed total precipitation amounts for an accumulation period of interest (e.g. 1, 3, 12, 48 months), with the long-term historic rainfall record for that period.[149,150]

Soil Moisture Anomaly (SMA): The SMA indicator is derived from anomalies of estimated daily soil moisture (or soil water) content - represented as standardized soil moisture index (SMI) - which is produced by the JRC’s LISFLOOD hydrological model, and which has been shown to be effective for drought detection purposes.[151]

FAPAR Anomaly: The FAPAR Anomaly indicator is computed as deviations of the biophysical variable Fraction of Absorbed Photosynthetically Active Radiation (FAPAR), composited for 10- day intervals, from long-term mean values. Satellite-measured FAPAR represents the fraction of incident solar radiation that is absorbed by land vegetation for photosynthesis and is effective for detecting and assessing drought impacts on vegetation canopies.[152]

LEVEL	COLOUR	CLASSIFICATION CONDITION
Watch		SPI-3 < -1 or SPI-1 < -2
Warning		SMA < -1 and (SPI-3 < -1 or SPI-1 < -2)
Alert		ΔFAPAR < -1 and (SPI-3 < -1 or SPI-1< -2)
Partial recovery		(ΔFAPAR < -1 and (SPI-3 $_{m-1}$ < -1 and SPI-3 > -1)) or (ΔFAPAR < -1 and (SPI-1 $_{m-1}$ < -2 and SPI-1 >-2))
Full recovery		(SPI-3 $_{m-1}$ < -1 and SPI-3 > -1) or (SPI-1 $_{m-1}$ < -2 and SPI-1 > -2))

Table 11: Classification scheme used for assessing the Combined Drought Indicator. Δ represents the anomalies, while m-1 is the month previous to the current one

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Exposure: Exposure is assessed by the European population density map at 100 m resolution using for example the WorldPop dataset or the Global Human Settlement Population dataset.

Output: An example of output map representing both CDI and exposed population to drought is reported in Figure 7. In this case, the spatial resolution of the exposed population is the same of the resolution of the population dataset.

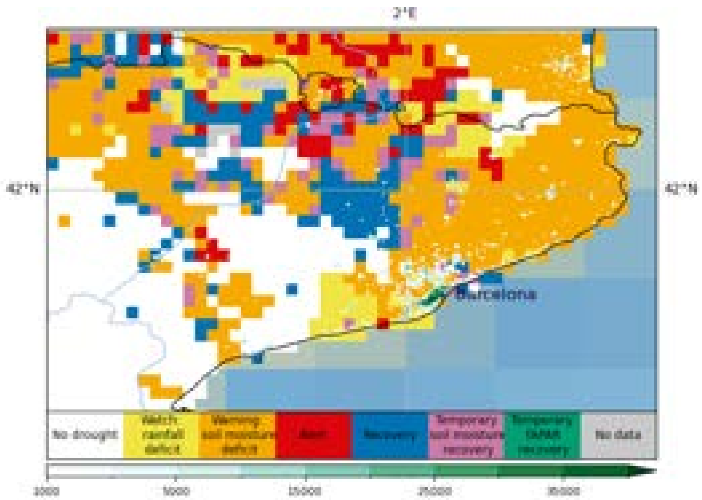

Figure 7. Combined Drought indicator and population number in the Catalonia pilot

Planned extensions: In the next versions of the we will assess CDI based on the different drought indicators assessed for future conditions.

4.3.4 Wildfire

Risk approach: Wildfire risk is defined as the likelihood that a wildfire characterized by a certain level of intensity can affect specific assets (e.g. buildings or properties in affected areas) or harm the population[153]. As in the previous workflow, we assess risk as:

R = H * V * E

Where V, E, and H are the vulnerability associated with the exposed elements, exposure, and wildfire hazard respectively.

In particular, first different hazard classes with associated wildfire probability are calculate. Second, damage is assessed as the product between vulnerability and exposure (expressed as the economic value of the asset). By following this procedure, it is possible to determine the potential damage for each exposed element from fires in different susceptible land use classes. Third, the hazard probabilistic component is added to the damage value to assess the probability of expecting a certain degree of damage due to wildfire phenomena. Finally, based on pre-defined loss thresholds, it is possible to define risk classes for different assets.

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Hazard: In this workflow, hazard Is defined as a combination of wildfire susceptibility and fuel type map (see Figure 8), i.e. types of vegetation and land cover based on their potential to contribute to the spread and intensity of wildfires. In particular, the hazard is defined by means of a contingency matrix in up to 12 different classes corresponding to different potential fire behaviours associated with several levels of likelihood. The wildfire susceptibility is defined as the static probability of experiencing wildfires in a certain area, depending on the intrinsic characteristics of the terrain.

In the toolbox, we produced a static susceptibility map at Pan-European scale by training a Random Forest Machine Learning model (sampling more than 30 countries) on burned areas from 2008 to 2022 with the geophysical (DEM slope, aspect, and land cover) and climatic descriptors collected for each of the studied countries[154–156] taking interannual climate variability into account. ERA5 climate data for the last 30 years climate average are used to assess annual average temperature, annual cumulative precipitation, annual average wind speed, annual maximum number of consecutive dry days, and annual maximum number of consecutive wet days. The results will be then extrapolated to all European countries. All available fire boundaries at pan European level are used to train the algorithm in order to identify most of the different fire regimes in Europe associated with different climatic and socio-economic conditions. Wildfire susceptibility for present climate conditions is derived from current climatic and land cover conditions.

In case of fuel type, we identify four classes of land-use are associated with four intensity levels. Vegetation classes present in the Copernicus global land cover map are aggregated in order to extract the following fuel classes:

- Croplands and grasslands
- Low flammable forests (such as broadleaf forests)
- Shrublands
- High flammable forest (such as coniferous forest)

Empirical probability density functions are then fitted for each of the different hazard classes.

HAZARD MATRIX		FUEL TYPES			
		1 grassland and croplands	2 low flammable forest	3 shurblands	4 high flammable forest
SUSCEPTIBILITY	1 Low	1 low intensity surface fires with low likelihood	4 medium intensity forest fires with low likelihood (broadleaves forests)	7 Medium intensity bushfire with low likelihood	10 High intensity forest fires with low likelihood (coniferous forests)
	2 Medium	2 low intensity surface fires with medium likelihood	5 medium intensity forest fires with medium likelihood (broadleaves forests)	8 Medium intensity bushfire with medium likelihood	11 High intensity forest fires with medium likelihood (coniferous forests)
	3 High	3 low intensity surface fires with high likelihood	6 medium intensity forest fires with high likelihood (broadleaves forests)	9 Medium intensity bushfire with high likelihood	12 High intensity forest fires with high likelihood (coniferous forests)

Figure 8: Wildfire hazard matrix combines wildfire susceptibility and fuel type map to classify the territory in 12 hazard classes including information on potential behaviour of wildfires and their likelihood to occur.

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Exposure: Using OpenStreetMap we identified fixed exposed elements and extrapolated information on different settlements such as healthcare facilities, economic/residential and educational buildings.

Vulnerability: Vulnerability is assessed by means of vulnerability curves that links the type of exposed element and intensity level (hazard). Each exposed element have a different vulnerability curve, which ranges from 0 to 1.

Output: An example of risk map for the wildfire risk workflow showing a set of assets in Bosnia and Herzegovina including healthcare, educational and economic facilities extracted from OpenStreetMaps.

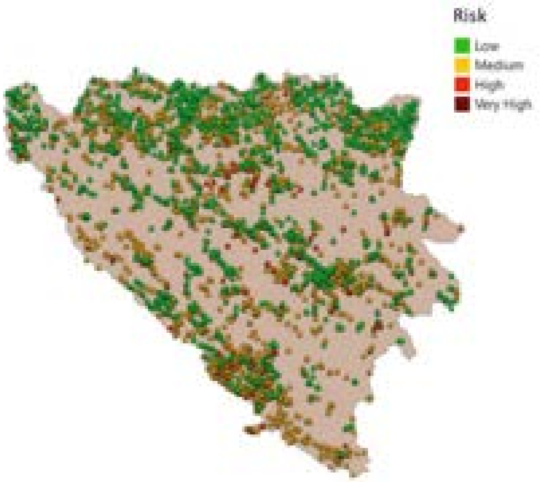

Figure 9: Example of a national risk map for a set of Point of Interest in Bosnia and Herzegovina. Risk is divided in 4 classes and ranges from low to very high.

Planned extensions: Future climate annual realizations will be provided based on the time-varying climate variability. The future analysis considers a time frame which spans from 2021 to 2060 using future climate projections from EURO-CORDEX. The different realizations of the wildfire susceptibility will be averaged from the several climate models to assess the wildfire hazards. Three climate change scenarios will be taken into consideration, i.e. SSP-1-RCP-2.6, SSP-2-RCP-4.5 and SSP-5-RCP-8.5.

4.3.5 Windstorm

Risk approach: This event-based windstorm risk workflow can be used to assess damages of a storm by combining hazard, exposure and vulnerability. The workflow is a simplified version of the work by [157]. In this workflow the hazard is a map with the maximum 3-second wind gust footprint of a storm developed using the ERA Interim and ERA-20C re-analyses. Footprints have a spatial resolution of 0.04 degrees (approximately a 4.4 km resolution). Exposure is determined by a class index in which the maximum damage to assets (expressed as damage per square meter of the asset)

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is reflected. Vulnerability is defined as a collection of damage curves where the wind gusts are matched to a percentage of the asset that is damaged.

Different components of the risk assessment contain different pieces of information: on the type of asset class and the maximum damage that can occur at the asset (exposure), the vulnerability curve of the asset (vulnerability), and the windspeed (hazard) at the asset location. With this information, the damage can be calculated per asset. Step one is to inspect the vulnerability curve and assess how much of the asset is destroyed at the given wind speed. This results in a fraction of the maximum damage value that occurs. Multiplying the maximum damage by the found damaged fraction results in the damage estimation of that asset.

Hazard: Using the Copernicus Climate Data store, historical windstorm footprints can be retrieved. Windstorm footprints for future scenarios will be developed in the coming versions of the toolbox, as also mentioned for previous risk workflows. Next to that, the CDS provides plausible yet synthetic storms that are physically realistic. These synthetic storms create an overview of possible events that can affect the area in current-day situations. Both datasets give the footprints of the maximum 3-second gust per 72 hours per grid cell. It is worth noting that while the historical windstorm footprint will allow the user to assess annual damage, the event footprint will provide the damage for that particular event.

Exposure: Exposure to windstorm is assessed by overlaying land-use from CORINE Land Cover data (100x100m resolution) information with Open Street Map to assess the coverage of building types. For each land-use class it is then known the percentage of each cell consisting of assets like residential, commercial, industrial, and other land uses, that can be associated with the vulnerability curves. Each land cover type is also associated with a maximum damage per square meter. A first estimation of the maximum damages is based on JRC maximum damage estimates per country. The PAGER database is used to add additional exposure characteristics to the buildings, differentiating between 106 different building types.

Vulnerability: The potential damages is assessed using the building characteristics as a starting point. This is done by aggregating the 106 building types from the PAGER dataset with the damage curves proposed by Feuerstein et al. (2011)[158] for six different building types. These building types are (i) weakest outbuildings, (ii) outbuilding, (iii) strong outbuilding, (iv) weak brick structure, (v) strong brick structure and (vi) concrete building and the damage curves are reported in Figure 10.

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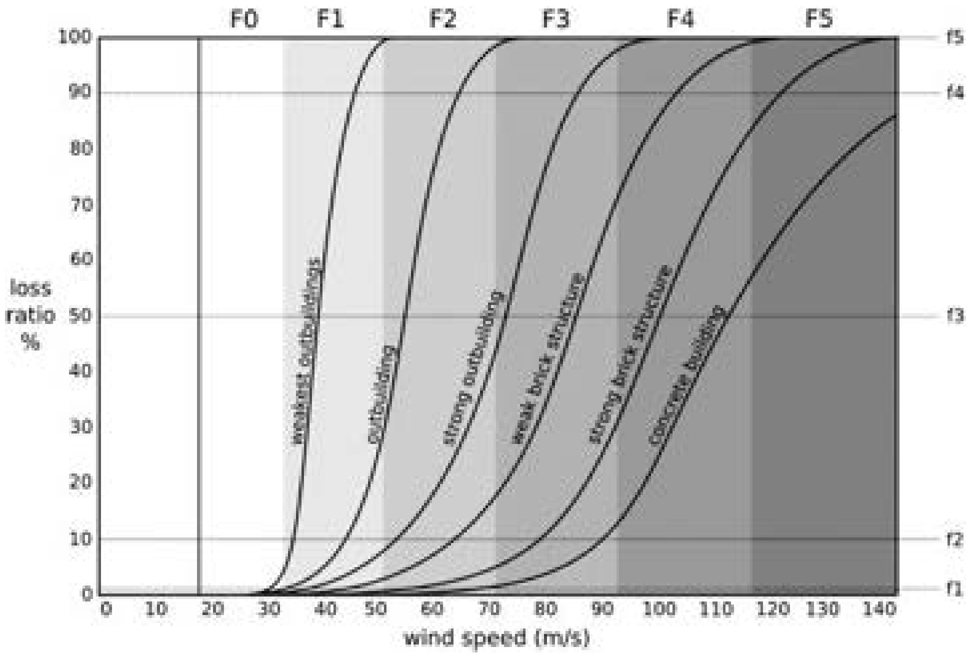

Figure 10: The six damage curves based on Feuerstein et al. (2011)[158]

Output: The final output of this risk workflow is a damage map with the spatial resolution of $100m^2$.

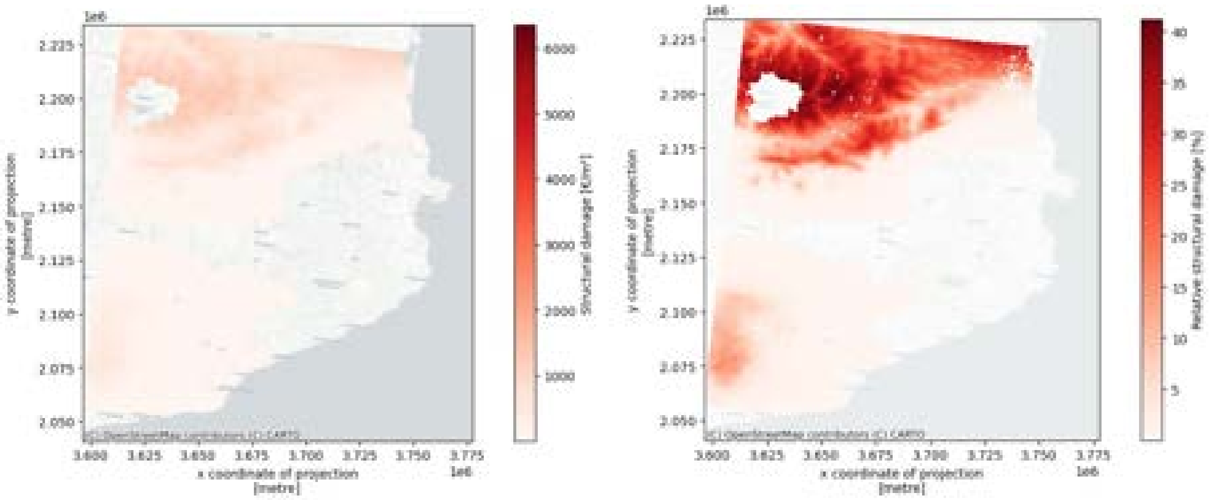

Figure 11. Absolute (left) and relative (right) structural damage maps for a specific storm event.

Planned extensions: Also for this workflow, the planned extension are mainly linked to implementation of future scenarios of hazard, vulnerability, and exposure data

4.3.6 Blizzard

A blizzard is a severe storm condition defined by low temperature, sustained wind or frequent wind gust and considerable precipitating or blowing snow.

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For blizzard conditions we used of following impact indicator taking into account the exposure of critical infrastructure, i.e., roads, rails, power lines and telecommunication to the hazard: Tmean ≤ 0 ^{o}C, Rs (snow amount) ≥ 10 cm and Wg (wind gust) ≥ 17 m/s.[159] This impact indicators are defined based on an extensive literature review, media reports, surveys conducted with European Critical Infrastructures operators and case studies in the EU RAIN project. The impacts and consequences of blizzard on critical infrastructure and transport system are related to i) fallen trees on roads, rails and electricity lines, ii) snowbanks, slippery roads, poor visibility, rail points may get stuck; and iii) accumulated snow on structures and power lines.[159,160]. As a consequence, we observe an increased rate of injuries and accidents in road traffic (2-4 times more accidents compared to the mean), delays, and cancellations in all transportation modes. In addition, wind power failure, damaged buildings: detached roofs and falling scaffoldings can also occur.

Risk approach: risk can be assessed following the framework presented by Aznar-Siguan and Bresch (2019)[161] for extreme weather impact. Risk is expressed as the combination of the probability of a consequence, hazard intensity, and exposure of assets.

Hazard: Probabilities of blizzards for the past climate (1981-2010) and changes in probability by 2021-2050 and 2071-2100 compared to 1971-2000 are publicly available from RAIN: Pan-European gridded data sets of extreme weather probability of occurrence under present and future climate (collection). Probabilities of blizzard for past climate were computed from ERA-Interim reanalysis at a horizontal resolution of 0.7°. Changes in annual probabilities of blizzard in future climate were computed from set of six RCMs at 50 km spatial resolution produced in EURO-CORDEX (SMHI-RCA4-CanESM2, SMHI-RCA4-NorESM1, SMHI-RCA4-IPSL-CM5A-MR, KNMI-RACMO22E-EC-EARTH, KNMI-RACMO22E-HadGEM2-ES and MPI-CSC-REMO2009-MPI-ESM-LR) for RCP 4.5 and RCP 8.5 emission scenarios. Examples of probability maps produced in the EU-RAIN project are given in Figure 12.

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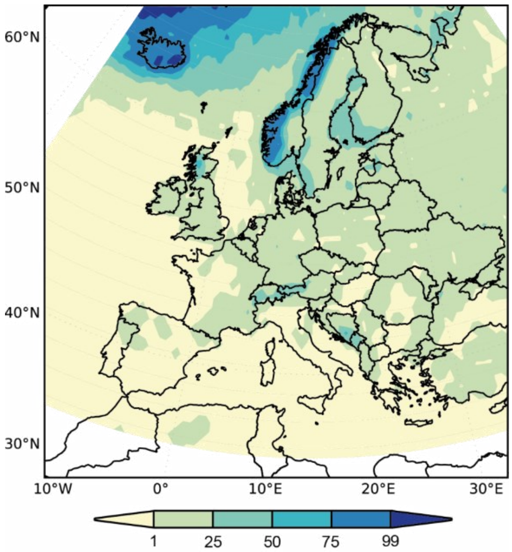

Figure 12: Annual probability (%) of blizzard during the period 1981-2010 based on ERA-Interim data. (From Groenemeijer P. et al. 2016, produced by FMI)

For computing higher resolution probabilistic data on blizzards, the newer generation of reanalysis data, i.e., ERA5 or ERA5-Land and climate projections will be implemented in the toolbox.

Exposure: To characterize exposure of assets, we use infrastructure data (OSM or the Critical Infrastructure Spatial Index (CISI))[162] or buildings data (OSM or EU buildings inventory).

Vulnerability: For the wind gusts component, damage functions for infrastructure and buildings will be used from the windstorm risk workflow (section 4.3.6). See section on planned extensions.

Output: Expected output are risk maps having the same spatial resolution of hazard input as exposure and vulnerability data are represented by polygons.

Planned extensions: For the coming version of the toolbox, we will compute changes in hazard probability using high resolution climatic data. Moreover, future scenarios based on EURO-CORDEX with 0.11°x0.11° spatial resolution will be used. Finally, we will assess blizzard damage functions for snow amount and mean temperature, which are currently unavailable. Therefore, we will account for exposure only until blizzard-specific damage functions have been developed.

4.3.7 Snowfall

Heavy snowfall may cause many disruptions and impacts in various sectors. However, the impacts and consequences of this hazard depend on the affected sector, infrastructure and preparedness of society that varies over Europe. For example, already a few centimetres of snow can disrupt road traffic, but doesn't normally cause any harm to energy infrastructure. Many weather services have three warning levels based on the severity of expected impacts, which are typically different for

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different sectors of infrastructure. There is a large variation in the national warning criteria or thresholds.

We use of impact indicators defined and applied in earlier studies[159,160,163] for assessing the impact of heavy snowfall on transportation and critical infrastructure. Similar to blizzard, the impact indicators for heavy snowfall were defined taking into account the exposure of critical infrastructure (roads, rails, power lines, telecommunication) to the hazard. We define two categories of events, characterized by qualitative thresholds:

1st threshold: Some adverse impacts are expected, their severity depends on the resilience of the system, transportation is mainly affected.

2nd threshold: The weather phenomena are so severe that is likely that adverse impact will occur, CI system is seriously impacted.

Threshold	Impacts	Consequences
Rs ≥ 6 cm	Reduced friction and slipperiness on roads, when combined with low temperature and wind, rail points may get stuck.	Increased accident rate in road traffic, reduced road capacity, road closures, possible delays and cancellations.
Rs ≥ 25 cm	Slippery roads, accumulated snowbanks. Poor visibility. Accumulated snow on power lines, structures and trees.	Disturbed traffic, high accident rate, closed roads, delays and cancellations of trains. Broken tree limbs or fallen trees on power lines, damaged or broken power lines, power outages. Limited access to repair equipment. Collapsed roofs.

Table 12: Impact thresholds for snowfall (Rs/24h, 1 mm precipitation=1 cm of snow).

<u>Risk approach</u>: The same risk approach used for blizzard is used.

<u>Hazard</u>: Mean annual number of days with snowfall exceeding the two impact thresholds are available for 1981-2010 from RAIN: Pan-European gridded data sets of extreme weather probability of occurrence under present and future climate (collection). Mean annual number of days with snowfall over 6 cm and 25 cm during past climate are computed from E-OBS dataset, horizontal resolution 0.25°. Examples of probability maps for heavy snowfall produced in EU-RAIN and published in Groenemeijer P. et al. (2016)[160] are shown below.

Changes in annual probabilities of snowfall in future climate are also computed from set of six RCMs at 50 km spatial resolution produced in EURO-CORDEX (SMHI-RCA4-CanESM2, SMHI-RCA4-NorESM1, SMHI-RCA4-IPSL-CM5A-MR, KNMI-RACMO22E-EC-EARTH, KNMI-RACMO22E-HadGEM2-ES and MPI-CSC-REMO2009-MPI-ESM-LR) for RCP 4.5 and RCP 8.5 emission scenarios.

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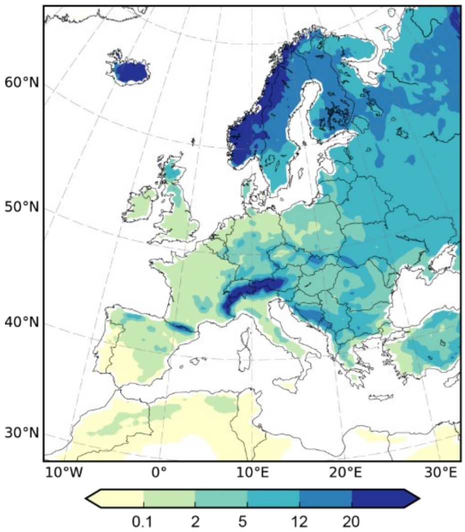

Figure 13: Mean annual number of days with snowfall exceeding 6 cm during 1981-2010, based on E-OBS data. (From Groenemeijer P. et al.[160], produced by FMI).

Exposure: To characterize exposure of assets, we can use infrastructure data (OSM or the Critical Infrastructure Spatial Index (CISI)) or buildings data (OSM or EU buildings inventory) (see Table 9).

Vulnerability: Damage functions for heavy snowfall based on different snowfall thresholds currently do not exist and we plan to include them in the next version of the toolbox. Therefore, in the current version of the toolbox we are accounting only for exposure.

Output: Same as the ones described in the blizzard risk workflow.

Planned extensions: Computing changes in annual probabilities using higher resolution data on heavy snowfall will be computed using newer generation of reanalysis datasets, i.e., ERA5 or ERA5-Land. Moreover, we will develop snowfall-specific damage functions.

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6 Annexes

Annex 1: Overview of reports used for the review in Section 3

Pilot	Type of document	Title	Year of publication	Responsible institution	Other information
Finland	NRA	*National risk assessment 2023*	2023	The Ministry of Interior	
	CRA	*Weather and climate risks in Finland – National assessment*	2018	Finnish Meteorological institute	Developed within the SIETO project
Latvia	NRA	*National Civil Protection Plan*	2020	The State Fire and Rescue Service (under the Ministry of Interior)	The NRA is embedded in the National Civil Protection Plan
	CRA	*(1) Risk and vulnerability assessment and identification of adaptation measures for health and well-being; (2)Risk and vulnerability assessment and identification of adaptation measures in the field of landscape planning and tourism. (3) Risk and vulnerability assessment and identification of adaptation measures for biodiversity and ecosystem services. (4) Risk and vulnerability assessment and identification of adaptation measures in agriculture and forestry. (5) Risk and vulnerability assessment and identification of adaptation measures in civil protection and emergency assistance. (6) Risk and vulnerability assessment and identification of adaptation measures in the field of*	(1;2;3;4) 2016; (5;6) 2017	The Ministry of Environmental Protection and Regional Development	The assessments were developed under the macro-regional project "Development of a proposal for the National Climate Change Adaptation Strategy, identifying scientific data and measures for ensuring adaptation to climate change, as well as carrying out impact and cost assessment" - EEA and Norway Grants (2009-2014)

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		construction and infrastructure planning.			
Catalonia	Regional risk assessment	**(1)** *Special Emergency Plan for Avalanches in Catalonia (ALLAUCAT)*; (2) *Special Flood Emergency Plan of Catalonia (INUNCAT)*; (3) *Special Snow Emergency Plan in Catalonia (NEUCAT)*; (4) *Special Plan for Seismic Emergencies in Catalonia (SISMICAT)*; (5) *Special Forest Fire Emergency Plan of Catalonia (INFOCAT)*; (6) *Special Emergency Plan for the Risk of Wind in Catalonia (VENTCAT)*	(1) 2014; (2) 2017-update; (3) 2021-update; (4) 2021-update; (5) 2021-update; (6) 2017.	Catalan Civil Protection Commission	Risk assessment is included within the Special Plans of Catalonia.
	CCIV	*Impacts and vulnerabilities in natural systems, socio-economic areas and territories*	2023	Catalan Office for Climate Change	The CCIV is one of the annexes of the Catalan Strategy for Adapting to Climate Change 2030 (ESCACC30).
Setúbal	Municipal risk assessment	*Municipal Emergency and Civil Protection Plan*	2014	Municipal Civil Protection Service	Risk assessment is included in the Municipal Emergency and Civil Protection Plan. The Plan is currently being revised.
	CCIV	*Assessment of current and future climate impacts and vulnerabilities in the municipality of Setúbal*	2022	Energy and Environment Agency of Arrábida	The CCIV was produced within the PLAAC project
Zilina					

Table 13: Risk assessments and climate risk/impact and vulnerability assessments taken into consideration in the desk reviews.

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Annex 2: Information from D2.1 used for the FSTP Call Package

The applicants are asked to provide background information and a proposed methodology to carry out the CRAs supported by CLIMAAX. From Deliverable 2.1 the following supporting material can be included in the description of the call for proposals:

- **Description of the governance structure relevant to the CRAs:** the description in each of the pilot regions (section 3.x.1 and underlying subsections Governance framework, Risk strategies, Institutional framework, Partnerships, Financing, Resilience ranking) can be referred to as an example of such a description.
- **Description of current risk assessment procedures and tools**: the description in each of the pilot regions (section 3.x.2 and underlying subsections Legislative framework, Risk Identification, Risk Analysis, Risk Evaluation, Risk Communication, Risk Assessment Capabilities and Challenges) can be referred to as an example of such a description.
- **Sketch of the structure of the CLIMAAX toolbox** (Figure 4 in section 4.3)
- **Description of a collection of risk workflows** (floods, droughts, wildfire, storm, snowstorm) in section

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Annex 3: Pilot site questionnaire

Assessing current risk assessment practices and future needs for risk data of regional authorities in Europe

EU CLIMAAX project/ Workpackage 2

Status: Jan 11th 2023

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1. **Background information**

WP2 of the CLIMAAX project aims at sketching the design of the first version of the CLIMAAX toolbox. In order to better understand what kind of data and tools should be integrated in the toolbox, and to derive a clearer picture of the potential users of the toolbox, we propose first to conduct a series of expert interviews. The outcome of these interviews can be a stepping stone for the discussions at the kick off meeting of CLIMAAX where we will discuss the requirements of the toolbox.

The targeted experts are staff members of regional authorities in the pre-selected pilot regions already identified in the CLIMAAX proposal. Ideally, we should interview both experts interested in risk data and end-users/non-experts interested in the final risk information for planning and policy use. We start the interviews with a brief introduction of the project and the activities of WP2 and then pose a series of questions on your experience with risk data and risk assessment.

2. Survey

Introduction

Welcome to this interview and we appreciate your cooperation. This interview is part of the CLIMAAX project, and the overall goal of the EU project is to create an online toolbox for regional authorities to provide them with risk data for supporting them in conducting risk assessment studies. The motivation for this project stems from the trends that the risk from natural hazards is increasing due to climate change (CC). For example, the frequency and intensity of floods and droughts may increase because of CC. Furthermore, socioeconomic developments such as population growth and urbanization in exposed areas may also increase the risk and impacts from natural hazards.

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Better risk information on these trends may help the regional authorities to prepare for changing risk profiles and to develop adaptation measures to reduce risk. The goal of this interview is to understand what risk information is already available or would be useful for the regional stakeholders; ask about their experience with risk assessments; and use this expertise to design a new CLIMAAX toolbox. In this manner, we are able to develop a toolbox that accounts for local knowledge and user needs, thereby increasing applicability for local to regional risk assessments. Please write your detailed responses to each question below.

Questions

1. **Background information**

1.1 What is the role / responsibility of your organization?

- What are the main natural hazards in your region?
- What were the most recent hazards in the region?

1.2 Are you involved in climate adaptation projects or projects that deal with implementing measures to reduce climate risk?

- No
- Yes: What kind of projects? What kind of measures: hard measures (reservoirs, dikes, etc.) or soft measures (spatial planning like zoning, insurance systems, etc.)

1.3 Defining risk from natural hazards:

- How do you define risk from natural hazards?
- Are you aware of the UNDRR definition of risk, where risk is determined by hazard, exposure and vulnerability?
  - Can you try describe each of these three components?
- Why do you need to assess the risk from natural hazards? What is the ultimate goal of doing a risk assessment according to your opinion?
- What data do you need for assessing the risk from natural hazards?

2. **Current risk information at the organization**

2.1 Do you have a department responsible for risk information?

- No
- Yes:
  - Who collects the data?
  - How many people work in this department and what are their roles?
  - Do you also work with models, such as hydrological models, to simulate floods or droughts? Or perhaps impact models? Please describe these models and their role in risk assessment.

1.2 Are you involved in any risk assessment study to map the risk from climate hazards?

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- No:
  - Will your organization be involved in future risk assessments?
    - No
    - Yes: What is the reason your organization will be involved in RA: Are there policies that require risk assessment? Please explain.
  - Which type of data and risk information would you be interested in?
- Yes:
  - Who initiated this risk assessment?
  - Is the risk assessment related to any national or EU policy (e.g. EU flood directive)
  - To who should you report the risk assessment (e.g. a regional authority, ministry)
  - Is there a protocol that you should follow for doing the risk assessment? Which steps do you follow in the risk assessment?
  - Do you use any toolbox or a data portal for retrieving data for the risk assessment?
    - Can you describe these toolboxes or portals. What type of data do they provide?
    - What are the pros and cons of these data portals?
    - Do you download data from data portals and analyze them locally (using GIS/python or similar)?

2.3 Current Risk Data & Analysis Methods

- Could you try to describe the data that is currently used in your organization:
  - Hazard (spatial maps with extent, return period, etc.)
  - Vulnerability (socioeconomic data? Response and recovery?)
  - Exposure (people, buildings, infrastructure etc.)
- Do you have future projections of risk information?
  - Do you use climate scenarios? Please explain.
  - Do you use socioeconomic scenarios? Please explain.
- Which analysis methods & tools do you use in your organization (e.g. GIS, python or similar)?

3. Improvements in Risk Assessment: Data and Methods

3.1 What were the main bottlenecks in conducting the current and past risk assessments?

- Lack of data: if yes, please describe per risk component Hazard, Exposure, Vulnerability (H, E, V)?
- Lack of guidance: no templates, no clear stepwise plan?
- No generic data format (NetCDF, etc.)
  - Is there a preferred data format you would like to use?
  - Are you interested in raster data and/or polygon data (e.g. NUTS2)?

1.2 In terms of new data, what type of data do you need?

- Are you interested in risk assessments based on historical info?
  - e.g. using return periods
  - Or just data describing historic events using all aspects of risk (H, E, V)

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- Do you need (improved-) future scenarios
  - CC scenarios? If yes, what type of data? What resolution?
  - Socioeconomic data:
    - Urbanization
    - Population growth
    - Socio-economic indicators to quantify vulnerability of communities

3.3 Toolbox design & analysis methods

- Would you be interested in a data portal where you can download data and maps?
- Would you be interested in storing your own data in the CLIMAAX toolbox?
- Would you be interested in guidance on new analysis methods (e.g. statistics, Machine Learning (ML), conditional sampling techniques)?

4. Examples of risk data and data portals

- We here show some examples of risk data (H,E,V) in different formats – Which data would be most useful for you?
  - Hazards maps: raster, polygon (NUTS2)
  - Vulnerability: survey data, maps (raster/polygon), index
  - Exposure: tabular data, maps (raster/polygon)
- We here show you some examples of risk information of existing platforms and toolboxes. Could you provide some comments on these toolboxes?
  - Risk data hub
  - Copernicus

5. Other open issues

- Do you have suggestions for the design of the toolbox?

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Annex 4: Overview of pilot needs as established through the questionnaire and scoping sessions

Pilot site	**Main climate hazards**	**Risk assessment methods**	**Data needs**	**Desired outcomes**
Latvia	Heavy rain, sea-level rise & coastal floods, river flood, flash flood, flooding due to snowmelt, drought, wildfire, winter storms, coastal erosion	Mainly focused on the monitoring indicators for different risks	High-resolution hazard projections. Socio-economic information, vulnerability drivers, exposure data (land use, urbnaization and population projections) in raster format	**1)** technical guidelines on how to perform a comprehensive risk assessment; **2)** bridge the gap between institutions and policy-makers
Catalonia	Wildfire, flash flood, sea-level rise & coastal floods, drought, extraeme heat, snow, wind storms, heavy rain	R = H x E x V; Expected losses (persons, property damage) due to exposure to a certain hazard in a certain area and period	High-resolution historical raster-based hazard data. Hazard future projections (5,10,25,50 y..) and by climate scenarios. Spatially coherent set of historical socio-economic data (exposure and vulnerability). Urban planning future projections. Land use planning projections.	**1)** evaluation tool for early warning systems; **2)** risk assessments that incorporate climate change projections
Zilina	Flash & river flood, drought, heatwaves, wind storms	Hazard-focused, event-based assessments with impacts on critical infrastructure and sensitive places; risk assessments based on e.g. satellite data, not local data (outsourced, no	Structured inventory of local to European datasets available for Zilina (hazad, vulnerability and exposure); future projections of H, E, V	**1)** methodology and guidelines on how to calculate risk, with the goal of implementing adaptation plans based on risk assessments; **2)** scenario based approaches (both climate and demographic/socio-economic scenarios)

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		own expertise available)		
Finland	River & urban flooding, wildfire, wind storms, snow blizzards, thunderstorms	Mostly limited to informing about hazards and their spatial and temporal extent	Wind direction, humidity and vegetation data. Projections of how vegetation, humidity and population distributions will change; also urbanization and socioeconomic indicators to quantify community vulnerability	**1)** short term warning tool; **2)** long term scenarios for the trends of wildfire risk; **3)** simulation of possible health effects caused by wildfires; **4)** tool able to predict how climate change is going to affect fire risk in Finland, focus on trends and related actions needed
Setubal	Estuarine flood, coastal flood, urban flooding, heavy rain, coastal erosion, heatwaves, wildfire, flash flood, drought, landslide, soil erosion, wind storm	Main focus on hazard and multi-hazard modelling based in the state of the art on climate change paths, evolution monitoring and early warning procedures and resources	Biodiversity loss and ecosystem services change data. Ecosystem vulnerability. Local socioeconomic data to assess impacts on population, public health, critical entities, infrastructures, heritage (they already have hazard, exposure and social vunerability data, but lacking capacity to process them).	**1)** test study to validate their risk assessment through comparison & updated version of their current maps. Set of tools which civil protection or mayors can use at strategic level and can help in decision making; **2)** evaluation of biodiversity vulnerability and related risk

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